

Flight of the Butterflies *in 3D*



Educator Guide

SK Films



Flight of the Butterflies

Flight of the Butterflies Educator Guide

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Welcome to the Fascinating World of the Monarch Butterfly!

Most school science curriculum includes the study of butterflies as well as concepts of migration, ecology, biodiversity and the process of scientific discovery.

This Educator Guide summary provides science information for educators, a source of curriculum specific activities, vocabulary, and web and print resources for further investigation. More detailed educational activities and background information on the film, ***Flight of the Butterflies***, are included on the enclosed disc of Educational Support Material and on the project web site www.flightofthebutterflies.com/learningcentre.

Flight of the Butterflies is now available in Giant Screen/IMAX® 3D and 2D theaters worldwide and could be playing in your area. Some theaters are part of museums with live butterfly pavilions. We encourage you to schedule a field trip to see the film in conjunction with exploring activities in this Educator Guide and Support Materials. By seeing the film, students will gain an appreciation for the monarch butterfly, its remarkable ability to navigate, orient and migrate, the unique Super Generation that makes the longest known insect migration on Earth, why and how hundreds of millions of butterflies migrate thousands of miles every year, and how their over-wintering sites were discovered.

The University of Minnesota's **Monarchs in the Classroom** program provided valuable input for this project, the U.S. **National Science Foundation (NSF)** provided generous funding, and the project's advisory team includes several of the world's top monarch butterfly experts, who continue to follow and scientifically investigate the monarch and its migration from Canada, across the U.S. to Mexico.

The study of the monarch also fits in very well with the growing area of Citizen Science/Science Engagement efforts established around the world. Thousands of individuals contribute to our knowledge of monarch biology and conservation by providing data to various research programs such as those from the Monarch Larva Monitoring Project, Journey North and Monarch Watch, as well as others. In fact, citizen scientists played a vital role in helping Dr. Fred Urquhart search for and discover the monarchs' overwintering sites in the mountains of Mexico – a story also told in the film.

We are sure that the film and this Educator Guide package will stimulate your young students to make the next great discoveries about the monarch butterfly. We wish you the very best in your exploration of monarchs and salute you for the work you do everyday in the classroom.

Sincerely,

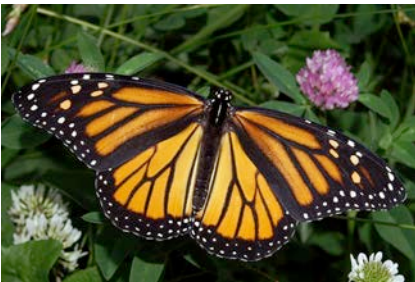
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Monarch Butterflies Background Information

History of Discovery

The monarch butterfly is an ancient tropical species, millions of years old. Thought to have originated in the Mexican and Central American mountains and valleys, it eventually invaded warming northern regions driven by its search for its precious food source, the milkweed plant. Milkweed thrives in disturbed soil, and its northward spread followed the development of civilizations in North America as Europeans arrived and cut down forests and cleared the land. Additionally, as the planet warmed, milkweed spread all over the U.S. and up into Canada, and monarch migratory paths closely followed milkweed sources.



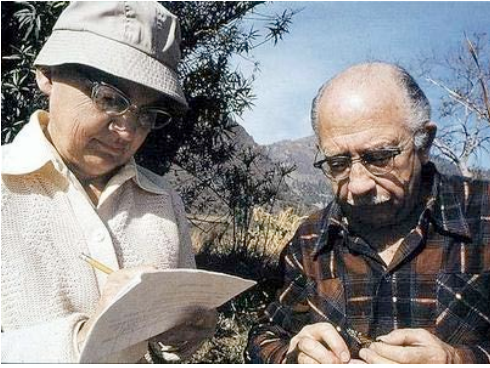
Adult monarch butterfly (*Danaus plexippus*)

The butterfly's Latin name is *Danaus plexippus*, inspired by the Greek myth of Danaus, whose daughters fled their homeland to avoid forced marriages. The long monarch journey recalls the daughters' flight. The Giant Screen film opens with a monarch called Dana.



King William III, Prince of Orange

Early U.S. settlers from Europe named the monarch after the popular British King William III, Prince of Orange (1650 to 1702). Others nicknamed it the King Billy butterfly (short for William), and still others named it the milkweed butterfly (for the sole food source for the larvae/caterpillar stage).



Norah and Fred Urquhart

Dr. Fred Urquhart, his wife Norah and their team spent almost 40 years to find the monarch overwintering sites in Mexico. They spent many years perfecting the right tag that would stay attached to the front wing. They started the Insect Migration Association and recruited and taught thousands of volunteers in Canada and the U.S. to tag butterflies in hopes of understanding their migratory paths and finding where they disappeared for months at a time.



August, 1976 National Geographic featured the monarch sanctuaries' discovery (Courtesy: National Geographic)

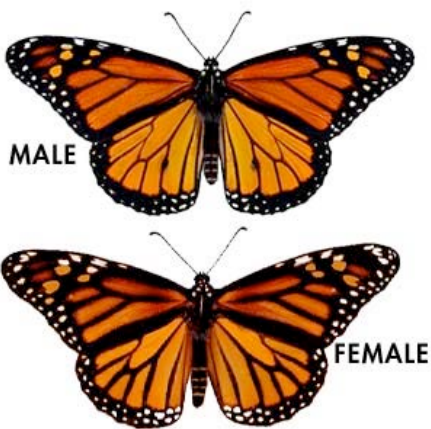
One of Dr. Urquhart's first volunteers in Mexico – Ken Brugger and his wife Catalina Aguado found the butterflies' winter roost on Cerro Pelon in central Mexico in 1975. A National Geographic article by Bianca Laviés featured the discovery in the August, 1976 issue.



Butterfly sanctuary (Reba Batalden)

When Urquhart finally visited the Mexico sanctuary with Norah, Ken, Catalina and Bianca, he still did not know whether these were indeed the same butterflies that came all the way from the northern U.S. and southern Canada. While Urquhart was resting on a log, one of the branches broke off and many butterflies cascaded to the ground. He noticed a white object and realized it was a tag – one of his, applied by two schoolboys in Minnesota, Dean Boen and Jim Street, with their teacher, Jim Gilbert. There is often quite a bit of luck in scientific research and discovery!

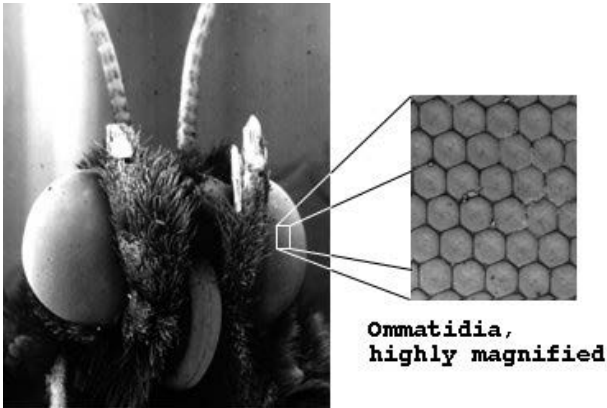
Monarch Butterfly Features/Senses



Male and female monarchs (Monarch Watch)

The adult butterfly weighs about half a gram with four wings and six legs – though the first pair is held so closely to the body that to most people it appears that the butterfly only has four legs. Females are darker colored and have wider bands of black scales along the veins. Males are slightly larger with two black pouches along a vein next to the abdomen.

Studies continue about monarch males and whether they produce pheromones, which they may secrete through special glands on the wings. But in contrast to their close relatives, monarchs do not require pheromones for successful mating. Scientists are still studying what role, if any, pheromones play in monarch mating rituals.



Monarch compound eye (Michelle Solensky)

Monarchs' large compound eyes are composed of thousands of tiny lenses, usually hexagon-shaped, called ommatidia, which gather and focus light. Monarchs also perceive ultraviolet and polarized light. Light travels in many directions – or planes – horizontally and vertically. This is what causes glare on a sunny day. Polarized sunglasses eliminate glare by reducing the number of planes of light you see. Monarchs have the natural ability to see polarized light. Variation in the polarization patterns in the sky allows many insects, and probably monarchs, to tell the position of the Sun even under cloudy conditions, thus facilitating orientation and navigation.

Monarchs sense much of their taste and smell from specialized receptors in their antennae, feet and mouth parts. Smell and moisture receptors on the antennae allow butterflies to sense the odors of flowers, water, host plants and perhaps each other. Females are equipped with a special set of probes or spikes on the first pair of legs that are rapidly tapped on leaves to “taste” the leaves to determine whether the plant being tested is an acceptable place on which to lay an egg.

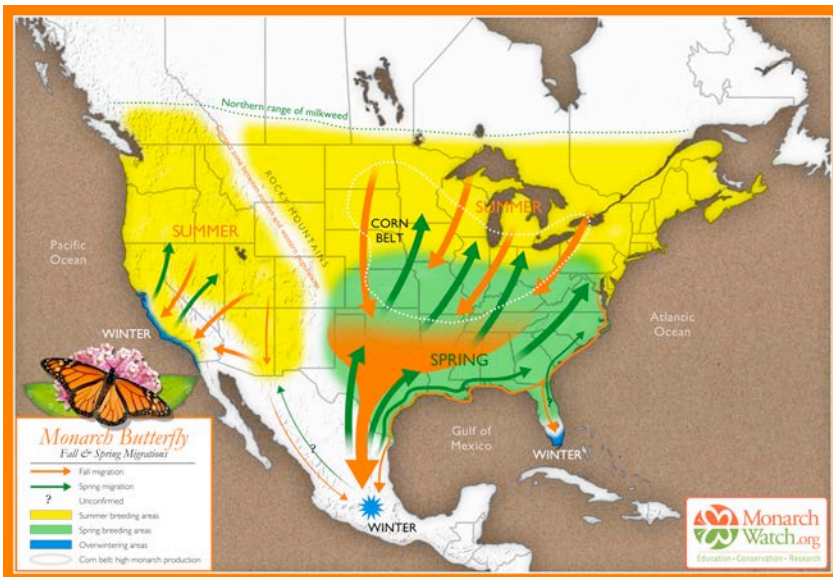
Hairs on the head probably aid monarchs in flight by sensing wind direction and speed. Other receptors, called proprioceptors, are sensitive to the position of body parts and gravity, probably sensing pitch and roll while in flight, making constant adjustments of the wings and abdomen to maintain a steady course. Tactile (touch) receptors help the butterfly position itself relative to plants and the ground – and to other butterflies when they are tightly clustered at overwintering sites. The paired filaments on mature monarch caterpillars are sensitive to touch as are the many fine hairs (tactile setae) along the body.

Monarch Migration



Monarchs in flight (Reba Batladen)

Many butterflies have long migrations, with some species showing spectacular migrations of millions of individuals. Monarchs are among a small group of butterflies, mostly related species that make a two-way migration in one generation. And, of this unique few, the fall migration of monarchs from Canada and the United States to overwintering sites in Mexico is both the longest known and most spectacular. How the monarch is able to accomplish this amazing feat is the subject of much speculation and research. Scientists are getting closer to understanding how monarchs sense changing environmental signals in both fall and spring and how they modify their behavior based on these changes to get to their destinations.



Monarchs' northern and southern migration routes (Based on original map design created by Paul Mirocha (paulmirocha.com) for Monarch Watch)

When monarchs take off for the southbound leg of their journey, people might see many hundred, even a thousand, in well-known viewing places like Point Pelee in Southern Ontario, Canada. Several migration routes in central southern Canada lead down through the central U.S. Most monarchs that migrate to Mexico originate from the northern breeding grounds east of the Rocky Mountains and north of the central United States (e.g. Oklahoma). A smaller monarch population that breeds in areas west of the Rockies overwinters at numerous sites scattered along the California coastline from San Francisco to San Diego.

Getting to Mexico isn't easy. It's not just a matter of flying south. If they only flew south, monarchs would end up in the Gulf of Mexico. Rather to get to Mexico, they set a course, and this course is different for different regions of the country. Monarchs passing through Washington, D.C. are moving west-southwest, near Atlanta the direction is almost due west, and in Lawrence, Kansas about south-southwest. How monarchs set these courses is unknown. Do they use celestial cues or magnetic information, some combination of the two or are other factors involved? Scientists are working to solve this puzzle. We do know that they use a combination of biological clocks, one set in the antennae and another in the brain that are used to stay on course.

Surviving the trip to Mexico involves elements of luck as well as specific adaptations that improve the odds of reaching the overwintering sites. The butterflies must avoid everything from vehicles to pesticides, spider webs, storms and the occasional bird that has yet to learn that monarchs aren't to be eaten due to their distasteful chemistry. In addition to their unique ability to set a course that will take them to the right place, monarchs have flight adaptations that improve the chances of arriving at the overwintering sites in good condition.

Rather than using powered flight – that is, constant flapping – monarchs use gliding and soaring to advance to the southwest. As the Sun heats the ground, thermals form. As monarchs encounter these warm rising air masses, they set their wings like hawks and spiral upward on the rising air. Once they reach the top of the thermal, they begin to glide. The glide ratio is about 3.5 to 1, meaning that for every 3.5 feet forward they lose about a foot in altitude. By flapping their wings 2-3 times every 20-30 feet, they can extend the glide until they reach another thermal. Thermals frequently carry monarchs to 1,000 feet, and some have been sighted a mile or more above the ground. This behavior conserves energy and saves their muscles and fragile wings. Most monarchs arriving at the overwintering sites are in remarkably good condition despite flights of up to 2,000 miles.

As monarchs move across the continent, they encounter relatively flat forests, farmlands and grasslands, as well as mountain ranges and large lakes. They deal with differences in topography in a variety of ways. When they encounter large lakes, if the weather isn't favorable, monarchs may accumulate for days waiting for favorable winds that will aid their passage. In mountainous areas they often ride the thermals that rise along the ridges, frequently taking the same pathways as migrating hawks. In relatively flat areas they move to the southwest in directions that are appropriate for the latitude and longitude in which they find themselves.

As the migration progresses, monarchs from as far east as New Brunswick and Maine and as far west as the front range of the Rockies converge on Texas, in effect funneling down to a 50-mile wide gap of cool river valleys between Eagle Pass, Texas, and Del Rio, Texas, their last stops before moving into the mountains of northern Mexico. Once in Mexico, monarchs tend to follow the mountains to the general area of the overwintering sites. Once they reach the overwintering area at the end of October, they begin to cluster on the oyamel fir trees on the ridge tops. With each day, as more monarchs arrive through November, the clusters in the oyamels become larger while moving toward more protected sites below the ridges. Distinct clusters are called colonies and some of these colonies can cover many acres with up to 25 million butterflies per acre. These colonies persist from November to March with some monarchs beginning to move northward by the end of February. The "Flight of the Butterflies" is about Dr. Fred Urquhart's quest to discover where and how monarchs overwintered. It is likely that what he found exceeded his expectations. In the film, he is

seen with his map, filled with known monarch migration paths. These lines represent paths that are known to contain thousands of butterflies, where there were numerous monarch sightings.

Two frequently asked questions about monarchs are “Why migrate?” and “Why migrate to these specific sites in Mexico?” Monarchs are not winter-hardy. Their resistance to freezing is minimal. To survive from one season to the next, they migrate to oyamel fir forests above 10,500 feet, a cool habitat where the daytime temperatures seldom exceed 65°F and the nighttime lows are seldom below freezing. The forest is a blanket that protects the monarchs. Monarchs remain relatively inactive through the winter, surviving by converting fats stored in the fall to blood sugars necessary to keep their bodies functioning. The monarch colonies are located in a relatively small area at 19.5 north latitude, but why this latitude (and longitude), and why these same locations in the forest each year to form colonies? Scientists don’t have answers to these questions – but there is no lack of speculation and interest.

A Day in the Life of a Monarch

Using the information we know about monarchs and their migration – and a little imagination – we can create a rough scenario of a day in the life of a migratory monarch. Most monarchs probably maintain a modest flight schedule, flying three to five 5 hours and advancing 30-50 miles to the SW when weather conditions favor flight.

- 9:00 a.m. Warmed by the Sun hitting the overnight roost site, the monarch fly a short distance to nectar at local flowers
- 10:00 a.m. Finishes feeding and starts migratory flight, stopping periodically for 10-15 minute feeding episodes
- 4:30 p.m. Stops migratory flight and feeds for at least 30 minutes on flower nectar
- 5:00-5:30 p.m. Searches for overnight roosting site, preferably one that is well sheltered with many other monarchs
- 5:30-6:30 p.m. Settles on roost for the remainder of the night, converts sugars from last nectar feeding to fats and blood sugar needed for the next day's flight
- 6:00 p.m.-9:00 a.m. Sleeps

This scenario is based on the flight of a late season monarch that averaged 61 miles per day from North Carolina to Austin, Texas, and probably required close to six hours of flight per day. Monarchs average about 11 mph with powered flight – slower when gliding and soaring.

Life Cycle



Egg on milkweed leaf (Michelle Solensky)

Larva (Denny Brooks)



Pupa (Karen Oberhauser)

Adult monarch (Fred Ormand)

All butterflies go through four stages – from egg (3-4 days), larva/caterpillar (10-14 days), pupa (10-14 days) to adult. The biggest and most remarkable growth stage is the larva/caterpillar stage, where it can increase its body mass by as much as 2,000 times. The entire process takes 30 days on average – the warmer it is, the shorter the cycle.

Genetic Sequencing

In 2011, U.S. scientists sequenced the monarch butterfly genome (DNA molecular structure) and discovered 273 million DNA units making up the genome. This discovery, the first of its kind for any butterfly and any migrating insect, may provide valuable information about how monarchs achieve their remarkable long-distance migration. Scientists believe they are gaining insight into how monarchs use a time-compensated Sun clock and into other physiological and behavioral adaptations. They also believe they have identified genes that may give visual input and central processing by the Sun-compass and that help monarchs store fat, build muscle, regulate temperature sensitivity, use special odorant receptors and other adaptations when in the migration mode.

The Milkweed Plant



Common milkweed plant (Karen Oberhauser)

Monarchs are dependent on milkweed and are often referred to as milkweed butterflies. Female monarchs lay not more than one egg per milkweed plant, usually on the underside of leaves, on this group of moderately to highly toxic plants. It is the only group of plants that serve as their host. Monarchs use about 30 of the more

than 70 milkweed species that occur in the United States and Canada. The most frequently used species is the common milkweed that is familiar to most people in the monarch's summer breeding areas.



Egg on milkweed leaf (Michelle Solensky)

As the larvae feed, they take toxins from the plant into their tissues. These toxins cause most vertebrates to become sick after eating a monarch. One such experience is enough, and many predators learn to associate the bright orange and black coloration of the monarch with something they should avoid eating. Unfortunately, most insect predators, such as ladybugs, wasps and parasitic flies, are not deterred by the toxins in milkweeds, and they make short work of the hundreds of eggs and larvae produced by female monarchs with the result that only a few percent survive to the adult stage.

The viceroy butterfly mimics the monarch. The monarch's distinct markings warn experienced predators not to eat them and to stay away. The viceroy does not eat poisonous milkweed and so does not taste bitter, but it clearly evolved to look like the monarch to trick predators.

Threats to Monarch Butterflies



Milkweed near plowed farmland (Wendy Macziewski)

The International Union for the Conservation of Nature (IUCN) considers the migration and overwintering behavior of the monarch an endangered biological phenomenon. Three main threats endanger the butterflies – milkweed habitat loss in the breeding ranges; degradation of the wintering habitat in the sanctuaries, mainly due to illegal logging; and climate change, which is causing more out-of-season storms with excessive rain often followed by freezing temperatures. In January, 2002, a freak storm killed approximately 400 million monarchs in the Mexican sanctuaries. Scientists were knee deep in dead monarchs.

For the Monarchs who make it to adulthood and survive the long migration south, they must face three more

enemies while they rest at the overwintering site in Mexico – two bird species and a mouse: Black Backed Orioles, Black Headed Grosbeaks and the Black-eared Mouse.



Monarchs roosting on trees (De Cansler)

Since there are millions of butterflies roosting on trees, they are vulnerable to the birds, who hunt in the morning and afternoon. The birds eat more males than females – this is due to female butterflies having more of the milkweed toxins in their systems. Once the sun goes down, the danger remains. Mice feed at night on any butterflies that rest on the forest floor.



Fire ants

Another growing threat is the fire ant, which can readily eat monarch eggs and larvae. It's a monarch predator immune to milkweed poison – and their numbers and range are vastly increasing. Climate change is allowing the ants to move farther north in the U.S., and their destructive impact on the butterflies, and on all ground-dwelling wildlife is developing at an alarming rate.

Conservation and Citizen Science

Many monarch butterfly citizen groups are dedicated to protecting the butterflies through research, lobbying and conservation activities – Monarch Watch, Monarchs in the Classroom, Monarch Larval Monitoring Project, Journey North, Monarch Butterfly Fund, Monarch Joint Venture, Xerces Society, Pollinator Partnership and Monarchs Across Georgia). The Mexican Federal Government (through the Monarch Joint Venture in the U.S.), the State of Michoacan and the State of Mexico also work diligently to protect the sanctuaries.

Protection of the Mexican sanctuaries began with a series of presidential decrees in the 1980s. In 2000, an additional presidential decree elevated the area to a federal biosphere reserve. In 2008, UNESCO declared the monarch butterfly reserve in Mexico a UNESCO World Heritage Site. The Mexican government has made logging near the sanctuaries illegal, but enforcement is difficult in such remote regions.



Tagged monarch (Monarch Watch)

Taggers recruited by the Urquharts played a critical role in the discovery of the monarch overwintering sites in Mexico. Dr. Urquhart was convinced that by tagging monarchs, the route or routes to an overwintering area could be deduced from the recovered tags. To further this vision Dr. Urquhart and his wife Norah created the “Insect Migration Association,” a large group of volunteers from many areas that tagged thousands of monarchs. The recovery of several tags in Mexico convinced Dr. Urquhart that monarchs overwintered in the mountains of central Mexico.

Ken Brugger, an engineer working in Mexico, responded to a newspaper ad posted by Dr. Urquhart asking for volunteers to search for the monarch overwintering sites. After a number of tries, Ken and his wife Catalina Aguado were guided to a colony on Cerro Pelon on January 2, 1975, and to another on February 2 on Sierra Chincua. The Urquharts visited these newly discovered colonies in the following year. It was here that Fred Urquhart found a tag that had been attached to a monarch in Minnesota by two schoolboys. This tag confirmed his long-held belief that the butterflies in Mexico originated in the northern breeding areas of Canada and the United States.

In 1992 shortly after the Urquharts, then long retired, terminated the Insect Migration Association, Chip Taylor created a tagging program at the University of Kansas that became known as Monarch Watch. Over the last 20 years, more than one million butterflies have been tagged through this program, and more than 16,000 have been recovered. Monarch Watch issues 200,000 tags each year. Analysis of the tagging results in still new information about the monarch migration. A 100-year-old woman living in Michigan, who first started tagging back with the Insect Migration Association in 1952, still reports her monarch sightings.

There is much that the general public can do to help sustain the monarch population. Taking part in one of the many citizen projects will provide data that help us to understand how monarch populations are doing, and how we can help them. Individuals, schools and local conservation groups can plant milkweed in gardens that lie along the migratory route. SK Films, the film’s executive producer and distributor, provides theaters showing the film a supply of milkweed seeds for visitors to raise awareness of the threat to milkweed and is

donating a significant portion of the film's proceeds to the conservation of monarch sanctuaries, specifically to Mexico's *Fondo Mexicano para la Conservacion de la Naturaleza* which manages the Monarch Fund with WWF Mexico.

Flight of the Butterflies Educational Content in the Film

The Giant Screen (IMAX) film will inform students of all ages and has more than 20 key science educational areas for teachers to explore and expand upon **before and after their students see the film**. This abundance of curriculum-specific educational information is one reason the **National Science Foundation** provided significant support to this project.

The Film's Story

The film tells two stories: the natural history story of the annual monarch butterfly migration – the longest known insect migration on Earth – and the almost 40-year search by a determined scientist to discover where the monarchs disappeared to each year from Canada and the US when the weather turned cooler.

Natural History

The film follows the life of four generations of a monarch family making the annual migration cycle, which takes one full year, starting with Dana (named for the monarch's Latin name *Danaus plexippus*) and her daughter, granddaughter and great granddaughter. Three generations fly north from Mexico. One "Super Generation" makes the entire trip back from the northern United States and southern Canada to Mexico to overwinter for several months and then completes the last short leg back to Central Texas to lay eggs. Then the cycle begins again.

The film production team followed the annual migration cycle and filmed in four different segments including twice in the remote, overwintering mountain-top sanctuaries in Michoacán, Mexico, and also in locations in the U.S. and in Canada, along the butterflies eastern migration route. This story is told in the film by the voice of a female narrator, actress Salma Hayek, following the migrations north and south in modern day.

One Scientist's Search

The monarch's overwintering sites were discovered in 1975 in the remote Transvolcanic Mountain Belt in central Mexico. The film follows the life of Dr. Fred Urquhart, starting as a young boy chasing butterflies and wondering where they went, to becoming a zoologist/biologist, teacher and university professor. Along with his wife Norah, he started the Insect Migration Association, enlisting thousands of volunteers across North America to tag hundreds of thousands of butterflies to track their migration route. This association ultimately helped Dr. Urquhart determine where the millions of butterflies were finally found, which National Geographic magazine featured as a cover story in August, 1976.

This story is told by the voice of our actor playing Dr. Urquhart at the time of the discovery, an elderly 90-year-old man looking back on his life until the moment of the discovery in 1975 and following the migration south.

The film follows the eastern North American monarch population during its migration cycle, which was the focus of Dr. Urquhart's discovery. He knew about the California colonies, but the tagging results focused on the major migration east of the Rocky Mountains. Monarchs in the western United States migrate to sites on the California coast, but they migrate much shorter distances and do not form large colonies like the hundreds of millions that aggregate in Mexico.

Natural History Story Elements Featured in the Film

- Monarch butterflies are an ancient tropical species making their annual migration for thousands of years.
- The film shows close-up detail of the four stages of complete metamorphosis of the monarch: egg, larva/caterpillar, chrysalis/pupa, and adult, and close-up detail of the adult butterfly body parts.
- For the first time ever on the Giant Screen, you will see inside the pupa in 3D through the science of M.R.I Scanning with recorded sound.
- The monarch is a highly-evolved migratory insect navigating and orienting itself for thousands of miles to a remote and small place to which it has never been.
- Monarchs can soar up to a mile high, and they weigh as little as a paper clip.
- Monarchs sense and avoid topographical features such as large bodies of water and high mountains, and funnel through small valley passes.
- The “Super Generation” makes the longest leg of the migration south to Mexico, and this generation lives 8-10 times longer than the other generations.
- To conserve energy, they try to catch free rides on prevailing winds or thermal airwaves, and females and males are not reproductive; the females do not lay eggs until overwintering in Mexico ends.
- Monarchs depend on milkweed plants to lay their eggs on. Milkweed leaves are the sole food source for the larvae/caterpillars, and their flowers are one source of nectar for the adult butterfly.
- Various natural predators eat around 90% of the eggs and caterpillars before they form the chrysalis/pupa.
- The monarch faces a number of human threats.
- A major threat to monarchs is habitat loss in their breeding grounds and the further destruction of milkweed plants on which they depend. Also, milkweed often grows on the borders between crops and farms. Larger farms are destroying their habitat by herbicide spraying and the planting of new forms of herbicide-resistant crops such as soy and corn, which kills milkweed in and around crop fields.
- In the Mexican sanctuaries, illegal logging has taken its toll. Despite the sanctuaries being government protected, logging is hard to regulate and still continues in these remote areas.
- Monarchs need tall trees to rest on during their overwintering period and they prefer evergreen trees. The film shows them covering every branch and tree trunk of the oyamel fir trees in the Mexican forests. Ideal overwintering sites cannot be too hot, too cold, too moist, nor have too much sunlight. The butterflies are in a semi-dormant state, and they rest except to fly to the ground once a day for a drink of water. The small amount of sunlight shining through the trees is just right to briefly awaken the butterflies but not too much to make them overactive and think it is time to migrate north again. The cutting of trees allows too much sunlight and reduces available roosting spots.
- Climate change could have a major impact on the butterflies. Major shifts in air and ocean temperatures in the mid-Pacific have been giving rise to warm moisture-laden air masses that are moving into central Mexico during the winter months, a period during which is normally dry. In January of 2002 and again in January and February of 2003 rainfall from such storms followed by freezing temperatures killed at least 70% of the overwintering butterflies. Unfortunately, the predictions are that such storms will become more frequent in the future.

Discovery Story Elements in the Film

- The film features the life of Dr. Fred Urquhart from a curious young boy to budding scientist, teacher and professor who, along with his wife, becomes leader of a monarch butterfly association of volunteer taggers, and the events leading up to the 1975 discovery in Mexico of millions of monarchs high up in the remote mountains. Many discussions can unfold about the perseverance and commitment it takes for a scientist to make a discovery and all the support he needs to accomplish such an achievement.
- The Fred Urquhart story can motivate young students to want to become scientists and make other discoveries about monarchs or about other species – even to discover new species, which is occurring daily.
- The film motivates monarch enthusiasts to help conserve the monarch butterfly and join protection organizations to tag and count the numbers of butterflies each year.
- The film shows several butterfly gardens and can lead to discussions about how students can plant milkweed and butterfly-friendly gardens that will supply nectar for monarchs.
- We know so much about one tiny creature and yet there is still much that needs to be further studied and discovered.

Education Standards

The activities included in this Educator Guide were developed within the context of current U.S. national science and mathematics education reforms.

The influence of the Benchmarks for Science Literacy published by the American Academy for the Achievement of Science as part of Project 2061, the National Science Education Standards prepared under the auspices of the National Research Council, and the Principles and Standards for School Mathematics is resident in every activity.

These are the same documents applied as resources or templates in curriculum development across the U.S.

Monarchs in the Classroom, University of Minnesota

The education activities in this Educator Guide were adapted from: Oberhauser, K. S. 2007. Monarchs and More: An insect and inquiry based curriculum. Monarchs in the Classroom, University of Minnesota. They are used with permission from the Monarchs in the Classroom program.

Educational activities were adapted by Maureen Sullivan, Maryland Science Center, with assistance from Abby Goodlaxson, Diane Bellomo and Pete Yancone, Maryland Science Center.

Educator Guide design by Kim Szondy, Kristin Pattik and Ilene Lundy, Maryland Science Center.

SK Films provided its research information from the preparation of the film, which was guided by assistance of the film's advisory committee of scientists. (See last page.)

Planting a Butterfly Garden

An Activity for All Grade Levels

Objective

Students will plan and plant a garden in their schoolyard.

Background

Planning and planting a butterfly garden is a positive action that your students can take to help provide monarchs and other insects with resources they need to survive. In addition, they will work together on a long-term project, planning where and when to plant their garden, deciding what equipment and supplies they will need and actually planting seeds or seedlings. Since butterfly gardening is becoming more and more popular, you may be able to visit an existing garden with your students to get ideas. Other resources include our references, garden supply stores and conservation and gardening organizations. Many schools work with a Master Gardener in their area in planning and caring for a school butterfly garden.

In this lesson, we include suggestions for creating a school garden. Many of the ideas and information come from an article by Jennifer Goodwin Smith in the January 1995 issue of *Science and Children* (p. 29-32). She planned and planted a school butterfly garden with sixth and seventh graders in Maryland and wrote the article to make it easier for others to do similar projects.

Procedure

Step 1: Planning to Plant

1. Get permission from school administration and maintenance personnel. It is especially important to gain the support of the people who maintain the grounds.
2. Discuss how butterflies and other insects use plants, and how they need special plants at different times in their life cycle.
3. Discuss the work involved in a garden, including maintaining the garden during the summer and raising money for seeds and other materials. Also brainstorm benefits of a garden (such as decreased noise and

Grades: K-12

Key Concepts:

- Gardens provide a habitat for many organisms.
- Humans can help preserve and create habitats for organisms.
- Seeds have various requirements for germination.
- Garden plants are either annuals or perennials.

Skills:

- Read for information
- Create representative drawings and symbols
- Use a scale measurement ratio
- Use a scale drawing to plant and identify flowers in a garden

Materials:

- Graph paper for planning garden layout
- Seed catalogs, gardening magazines, butterfly guides, books on butterfly gardens
- Seeds or seedlings
- Gardening supplies (soil, fertilizer, shovels, rake, hoe)
- Containers in which to start seeds (yogurt containers, egg cartons, nursery flats)

air pollution from reduced mowing, reduced soil erosion, a beautiful garden, food and shelter for many organisms).

4. Develop a timeline for the garden. If you start from seed, you will need at least three months. A good timeline is:

- *First month:* get administrative support, choose a site, hold fund-raisers if necessary, order seeds, germinate seeds.
- *Second month:* monitor seedling growth, design the garden.
- *Third month:* prepare garden site, transplant seedlings.

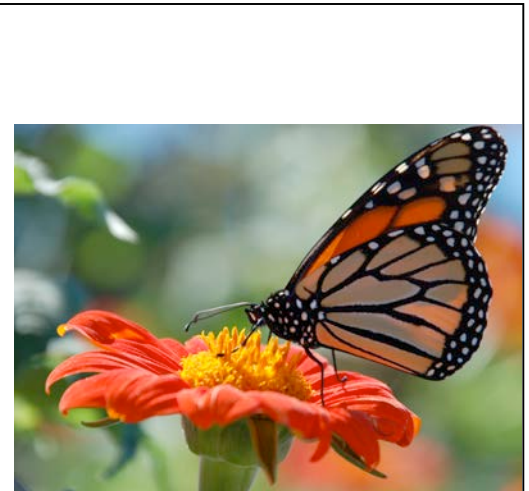
5. Decide on the criteria you will use to judge a site. Important considerations include available sunlight, level of foot traffic, visibility to school and community and vulnerability to vandalism.

Step 2: Planning the Garden

1. Choose the plants that you will use. Sources of information include seed catalogs, gardening magazines, books about butterflies and butterfly gardening, and other resources.
2. Encourage students to choose plants that bloom at different times. Perennials are good since they only have to be planted once, but including an area for annuals will allow future classes to participate in planting each year. Also consider plant height, color and length of blooming time.
3. Make suggestions as to the garden design, such as choosing colors that blend and making sure all plants are visible (i.e., tall in back, short in front).
4. Plan the garden together, using graph paper to draw a plan of what you will plant where.

Step 3: Starting Seedlings

1. Buy seeds (or plan where you will buy potted plants). Sources include gardening catalogs, hardware stores and nurseries. You may want to plan to use a combination of seeds and purchased plants. Plants should not be purchased until it is time to plant the garden.
2. Have students bring in yogurt containers, foam egg cartons and other containers in which to start seeds. You can buy, borrow or ask for donations of potting soil, fertilizer, straw, shovels, a rake, and a hoe.
3. Plant seeds. Punch a small hole in the bottom of containers, fill with soil, bury seeds according to instructions and place containers on trays to catch extra water. Students should be responsible for caring for their plants. They can also measure plant growth, germination time, and other variables and keep track of their progress in a science journal or lab notebook.
4. Keep seedlings in a sunny window or under grow lights.



Jim O'Leary

5. After 4 to 6 weeks, seedlings will be ready to transplant.

Step 4: Planting the Garden

1. Prepare the soil. Turn it over and add some fertilizer.

2. Plant seedlings outdoors. Make sure danger of frost is past.

3. Apply mulch to prevent soil erosion, maintain soil moisture and slow weed growth.

4. Set up a schedule for garden maintenance as a class. Tasks may include watering, weeding and replacing mulch.

5. Set up a time to observe the garden once a week. Keep track of what plants are present, which are blooming and what insects are seen in the garden.

6. Clarify a no pesticide policy.

7. Make a plan for caring for the garden over the summer. Parents are often happy to help, especially if they have been involved in planning the garden. The more people are involved, the less likely your garden will become a burden for a small number of people.

Flight of the Butterflies

(Film logo)

Classroom Activities

Grades K-2

Getting to Know Your Caterpillars

Objective

Introduce students to the monarch butterfly. Use brainstorming and list-making techniques to find out what they already know about monarchs. Then conduct hands-on observations of live monarch larvae. Students may make comparisons between monarch larvae and other stages of the monarch life cycle, such as the chrysalis/pupa and adult.

Background

This lesson is divided into two sessions that will allow the teacher to 1) assess what the students already know and what they would like to find out about monarchs and 2) provide an opportunity for students to make detailed observations of their monarchs. We recommend doing the first session before showing students the larvae and the second session as soon as the students receive the larvae.

In K-2 classrooms, teachers rather than students should be responsible for rearing the larvae (e.g., ensuring that the larvae are fed, their cages cleaned, etc.).

You can raise all the larvae in one large cage. If your room is organized around tables or groups of desks, you may want to divide the larvae into several smaller cages, such as milk-carton or ice-cream bucket cages. Each table or group of desks would receive one or two larvae and could watch them grow.

Procedure

Session 1: What do you know and want to know about monarchs?

1. Before showing students the larvae, brainstorm and list on chart paper: *What do you know about monarchs?*
2. Brainstorm and list on chart paper: *What do you want to learn about monarchs?*
3. Read a story about monarchs. See the Reference section for ideas.

Session 2: Observing Monarchs

Grade: K-2

Key Concepts:

- Brainstorming and list making helps organize thoughts before activities.
- Brainstorming and list making also helps students realize how much they know.
- Observations are a vital component of scientific inquiry.

Skills:

- Brainstorm and create lists
- Make detailed observations
- Make comparisons

Materials:

- Chart paper
- Larvae (see References)
- Small containers to hold larvae
- Magnifying lenses

1. Divide students into small groups or pairs and pass out a larva to each group. The larva can be in a small container like a plastic or paper cup or Petri dish with milkweed.

2. Brainstorm and list on chart paper the students' observations of colors, patterns, what the caterpillars feel like, behavior, their size, what their legs look like and their weight. Have magnifying lenses available. Encourage students to use as many of their senses as possible (except taste!). At this point, you may want to stress to the students that they should try to make accurate and detailed observations and not to make value statements (i.e.: *The caterpillars are pretty [or ugly].*). They will learn more about accurate observation in the *Data Collecting* activities. Sample questions to facilitate the brainstorming session are:

- Describe the size of the caterpillar.
- How do you think the caterpillars move? Do they have legs? Do the legs all look the same?
- What are they eating? How do they eat? Can you see teeth?
- What do the caterpillars do when they touch each other?
- What do they do in your hand? What happens when you touch them?
- Look at the black things sticking out of the front and back of the caterpillar? What happens when you touch these?
- Can you tell the front from the back of the caterpillar? How?
- Can you see eyes on the caterpillar?



3. Add observations to your list over time.

Additional Ideas for Practicing Observation Skills

1. Use the same techniques to observe the pupae or chrysalides.
2. Use the same techniques to observe the adults when they emerge. Keep adults in a cage, not a dish, but let the students handle them. Monarch scales do not come off as easily as those of many moths and butterflies, but the children will probably see some scales on their fingers. If you hold an adult close to a child's finger or arm, they will be able to feel the feet, or tarsi, clinging to their skin. Sample questions to facilitate a brainstorming session on adults are:
 - List similarities and differences between the adults and the caterpillars. Are their legs different? Are their eyes different? Do they both have heads? Do they have the same number of legs?
 - What does it feel like when the butterfly holds onto your finger with its feet?
 - How do the adults eat? Can you see their proboscis?
 - Can you tell the difference between a male and a female monarch?

- *What colors can you see on an adult?*
- *Describe the adult antennae.*

3. Have students make a model of caterpillars out of egg cartons joined with yarn or pipe cleaners. Kindergartners can paint or color them yellow, white and black; older students can make accurate representations of the color patterns.
4. Use paint, markers or crayons to copy the pattern on the larvae. How do the widths of the stripes vary? How many stripes are there before the pattern repeats itself? Use pictures in old magazines, calendars or books to find other patterns in nature.

What is Butterfly Habitat?

Make a Wall Mural

Objective

Students will learn about the concept of habitat through observation and make a large wall mural to illustrate a habitat that they have studied.

Background

A habitat is a place in which individuals of a particular species can usually be found. An organism's habitat contains the things that the organism needs to survive. By discussing the needs of monarchs, students will develop an understanding of the concept of habitat. They will then create drawings of plants in a monarch habitat to be included on a bulletin board or mural. This lesson works best if students can actually observe a monarch habitat; if you can take your students to a butterfly garden or nearby park or field, this would be ideal. However, they can also look at pictures or describe habitats they have seen in the past.

Procedure

1. Discuss what a monarch needs to survive and list these needs on a board. Your discussion should cover needs at different stages: egg, larva, pupa and adult. Discuss the concept of "habitat" with your students, telling them that an organism's habitat must include all of the things that it needs to survive. Students may identify many things as needs; this activity focuses on nectar sources (food for adults) and host plants (food for larvae).
2. Using books and other materials that you have provided, have students look for plants that are good nectar sources. Make a list of those that they find, or write the words on word cards and put these in a pocket chart. Some of them may have seen butterflies nectaring; include the plants they've seen on the list if they know their plant's name or can describe it well enough for you to guess what plant they mean.
3. Have each student make a full-page drawing of a plant that is a good nectar source for butterflies. Be sure to have them draw the whole plant, not just the flower. Use field guides, seed catalogues, books on butterfly gardening or actual plants as guides. Encourage students to draw more than one individual of the plant they choose. Make the drawings large enough to be cut out. Have students label them by copying names from the class list.

Grades: K-2

Key Concepts:

- An organism's habitat contains the things it needs to survive.
- There are many kinds of plants and animals in habitats.

Skills:

- Observation
- Recording observations
- Drawing
- Cooperative work

Materials:

- Plant field guides or other books with pictures of nectar sources and milkweed
- Large drawing paper
- Crayons or colored pencils
- Space on bulletin board or wall mural

4. Have each student make a full-page drawing of milkweed. Use field guides or the actual plant as a guide for student drawings. These drawings should also be cut out and labeled.
5. To create the monarch habitat, attach student drawings to the bulletin board or on a large piece of paper for a wall mural.
6. Students may add drawings of caterpillars and butterflies to their habitat mural, as well as other plants and animals.
7. If possible, take the class outside to a butterfly garden or nearby parks or fields. Have students look for the plants they identified for their monarch habitat and other butterflies or insects in the habitat.

Extension

If there is a nature area or butterfly habitat at your school or nearby, students may observe changes in the habitat over time by making periodic visits and recording their impressions and drawings. Have students visit the area in winter, noting the absence of plants, and again in the spring, looking for new growth. Discuss the changes that took place by comparing the student drawings to how the habitat looks in different seasons. You may want to take photographs of the habitat in each season.

Monarch Migration Game

Objective

Students will play a game that illustrates the challenges faced by monarchs that migrate to Mexico. These challenges include finding enough to eat, dealing with often adverse weather conditions and avoiding external sources of mortality.

Background

This game gives students a chance to pretend that they are monarch butterflies migrating to Mexico. While much of its appeal is that it is simply fun for students to play, it teaches students some of the hazards butterflies face on this migration and introduces them to the concepts of choices and tradeoffs for animals. It is best played on a rather large field with one end designated as the northern beginning of the journey and the other designated as the monarchs' destination, the overwintering grounds in Mexico.

To prepare for the game, read the background material on monarch migration and other available information. If possible, involve your students in the Monarch Watch tagging program. Study monarch migration and migrations of other animals with students.

Procedure

The goal of the game is for the students to get from Canada or the northern U.S to Mexico. It is not designed to be competitive, although some students will get there first. Adding "nectar cups," adults with tags and a water hazard all make the game more complicated, but add realism and excitement. An adult leader will stand on the edge of the field holding a large cardboard Sun and clouds. The students will only be able to travel when the Sun is raised in the sky and when it is not covered by a cloud. The leader will make the Sun set behind her/his back to indicate nightfall. The same leader, or another adult that can move close to the students, will read situation cards that present realistic conditions that monarchs might face.

1. Set up the playing field with signs for your location and Mexico at opposite ends. If desired, outline a large lake with rope or playground cones somewhere in the middle of the field. Also if desired, fill small cups with water or juice and place them around the field (not in the "water"). Scatter adult helpers, or

Grades: K-2, 3-6

Key Concepts:

- To survive their migration to Mexico, monarchs face many challenges.

Skills:

- Listening to directions
- Relating game activities to monarch migration biology

Materials:

- Kid-Sized Monarch Tags, one per child (teacher page)
- Situation cards (teacher page). These may be cut out and taped to index cards, if desired.
- Cardboard Sun and cloud (large enough to be seen from a distance)
- Signs that say Mexico and northern home of monarchs

Optional:

- 2-4 small cups/student (Dixie cups or medicine-sized cups work)
- Juice or water to put in the cups
- One drinking straw ("proboscis") for each child
- A long rope or playground cones to outline a water hazard
- Extra adults to act as roosting sites and monarch taggers (students can also do this)

about 1/3 of the students, around the field to act as night-time roosting sites. They can also be equipped with tags if you want to include a chase by monarch taggers in the game.

2. Tell students that they are monarch butterflies about to begin their journey from their location to Mexico. They need to think like a butterfly, and follow these rules:

- They must hop instead of walk or run and flap their arms like wings. Have them all practice this.
- If you have cups with nectar, they need to drink from a nectar cup every day through their “proboscis” (or every other day if you have lots of kids and a limited supply of cups).
- They can only “fly” when the Sun is out.
- When the Sun goes down, they must get to a roosting tree within five seconds. They must also get to a roosting tree when the Sun is covered with a cloud (tell the students this means rain, and monarchs can’t fly when it’s raining). Show the students how the Sun looks when it is out and how it sets behind the back of the adult in charge.
- If you use the lake hazard, they can fly over the lake, but if the Sun sets or is covered by a cloud while they are over the lake, they will drown. You can have them go back to the north side of the lake, or to the start, so that no students have to leave the game.
- At the beginning of every day, they must listen to the situation card and follow the directions.

3. Distribute a straw “proboscis” to each child.

4. One or two adults should stand on the edge of the field and hold the cardboard Sun and clouds. They should be ready to read one situation card at the beginning of each day.

5. Students should start near your location sign on one end of the playing field. They can start “flying” south when the Sun comes up. Have them keep an eye on the Sun and head for a roosting site if it goes under a cloud and when it sets.

6. The leader should make the Sun set often enough so that it takes at least five days to get all the way to Mexico and cover the Sun with clouds often enough to keep the students (butterflies) on their toes (tarsi).

7. At the beginning of each day, the leader should read a situation card. This tells students how fast they can fly and other weather conditions that will affect their flight.

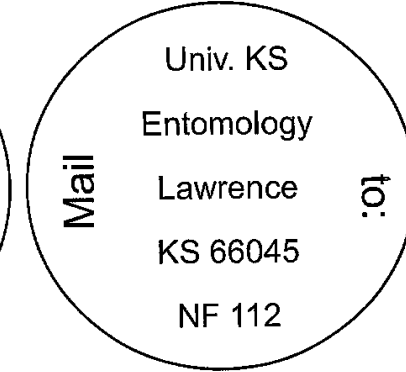
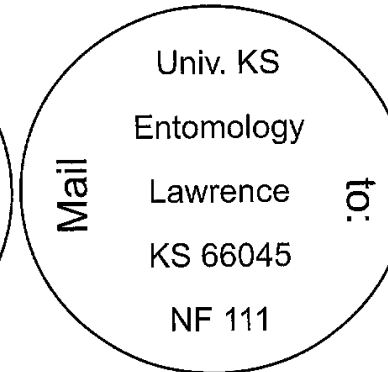
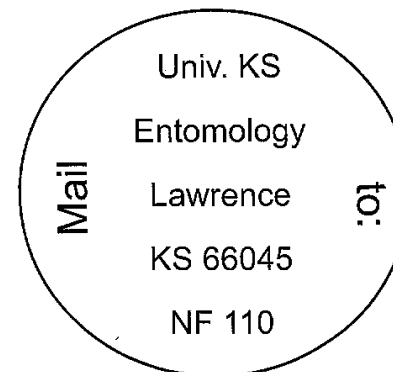
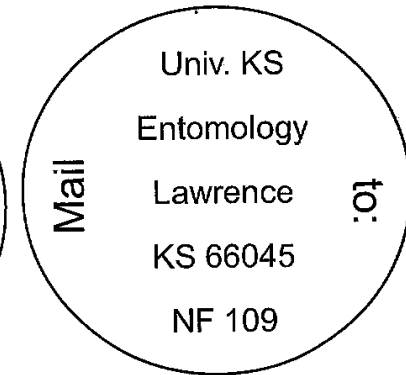
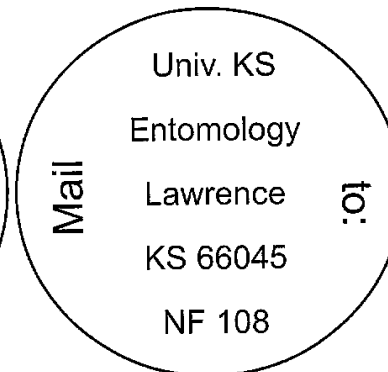
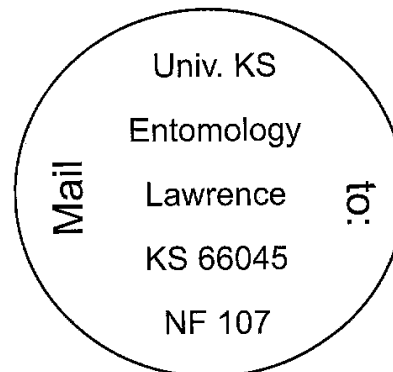
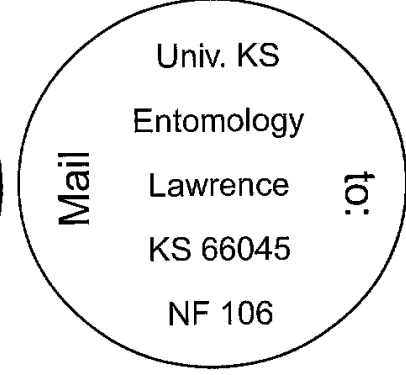
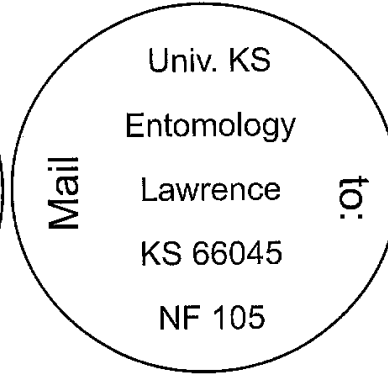
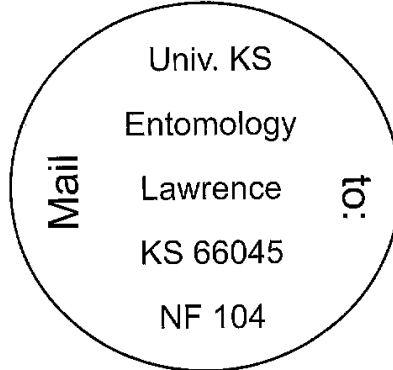
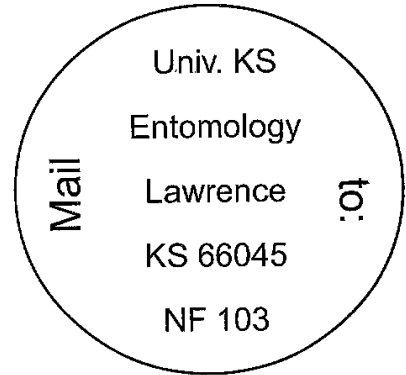
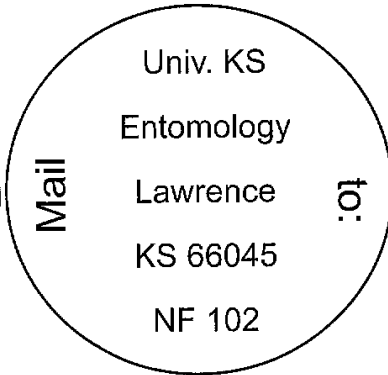
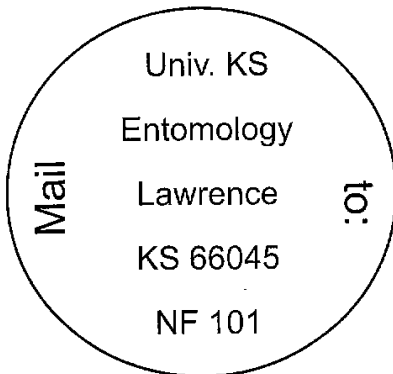
8. The game ends when all students have gotten to the overwintering site in Mexico.

9. After the game, discuss what aspects of the game were realistic and what hazards monarchs might face on their journey in addition to those in the game. Discuss how long the journey really takes and talk about the odds of successfully making the entire journey.

Situation Cards

<p>SUNNY, 55° – Shiver to warm up your flight muscles. Tell why you can't fly with cold muscles. Count to 10 slowly, then fly.</p>	<p>Sunny, 70° – Flowers for nectar are between 2 highways. Tiptoe away from your roost and find nectar.</p>
<p>SUNNY, 60° – If your tag is an odd number, you roosted on the sunny eastern side of the tree. Odd numbers fly first; even numbers shiver for 5 seconds, then fly. (This only works if students all have tags.)</p>	<p>SUNNY, 55° – Some flowers were killed by the frost last night, and there isn't much nectar. If your tag is an even number, you found nectar and may fly. (This only works if students all have tags.)</p>
<p>SUNNY, 70° – SOUTHWEST WIND – You want to go south, but the wind is blowing against you. You need to make up for the push of the wind. Hop backward toward the west.</p>	<p>PARTLY CLOUDY, 75° – Fly but watch the clouds for rain and keep your eyes out for safe roosting sites.</p>
<p>SUNNY, 75° – There is a north wind! Fly fast and far today.</p>	<p>RAINY, 55° – Stay at your roosting site. Discuss what weather is best for migrating.</p>
<p>People with nets are out tagging monarchs. You may be tagged, so fly fast. (Roosting sites should chase monarchs and tape a tag on any they catch.)</p>	<p>You've come to a big lake or the Gulf of Mexico. Go all the way to the west side of the field before heading south.</p>

Kid-Sized Monarch Tags



Flight of the Butterflies

(Film logo)

Classroom Activities

Grades 3-6

Keying Out Kids

Objective

Students practice sorting related things using a taxonomic key.

Background

Field guides are organized by similarities among the characteristics of plants and/or animals. Sometimes they include a dichotomous key, a tool for identifying a species by narrowing down options that limit description to certain features.

Procedure

1. Read the book *People* by Peter Spier as an introduction to how we are all alike and different.

2. Ask the students “*How can scientists figure out the name of an insect they have never seen before?*” By comparing physical characteristics that identify membership in a family, genus and species, an insect can be identified. Scientists classify organisms to create a system of knowing about and talking about them. Similarly, we organize many other things. Ask students:

- *How many of you have your clothes organized in your closet or dresser?*
- *How are they organized? Why?*
- *How are libraries organized? Why?*

3. Ask “*How can you tell different people apart?*” (hair color and shape, skin color, age, eye color, height, gender). Ask “*Why is clothing not a good way to tell people apart?*”

Explain that the system we use to organize libraries is like a key. Keys are ways of organizing things to help us find information easily. Pass out copies of the People Key and explain how it works. Practice with familiar people students know in your building as examples.

Each of the branches represents a physical feature that helps to tell people apart. By starting at the trunk and moving up the branches that correctly describe the person being “keyed out,” you will reach the very tip of an outermost branch. This is the person’s position in the key.

For example, if you were keying out a blue-eyed girl with straight brown hair and freckles, you would first move up the branch marked “female.” At the fork for your hair color, you’d move up the branch for brown

Grades: 3-6

Key Concepts:

- Everything can be sorted, or organized, by similarities and differences.
- Scientists sort, or order, organisms in order to share knowledge about organisms as they discover them, and in order to apply the knowledge to better understand other, related organisms.
- Keys are helpful tools for sorting (classifying) organisms, once you know how to use them.

Skills:

- Make observations
- Compare and contrast
- Use a dichotomous key

Materials:

- Copies of *People Key*
- *People* by Peter Spier or a copy of a key from a field guide to show your

and then the branch for blue eyes; you'd finish up at the end of the "freckles" branch. This is where you'd write that person's name. Have small groups of students key you out.

4. Assign partners and direct the students to key out each other on the diagram. They can add their names to the correct branch on the key you have on the overhead, bulletin board or chalkboard.

5. You will find that several people have been placed at a single position on the key. Ask these students to come to the front of the class and ask the class to discuss other characteristics that could identify them (height, hair length, shades of skin and so on). Discuss how each branch on the tree causes your classification to become more specific. Emphasize that while this key is like those used for other organisms, humans are all the same species to start with. You don't end this exercise identifying a specific "species" of person. With organism keys, we end up with specific species.

PEOPLE KEY





How Far Can A Butterfly Glide?

Objective

Students will create paper airplanes using a template provided and then modify this template to make the most efficient glider that they can. They will consider how factors such as wing position and shape affect monarchs' ability to fly long distances.

Background

Flight in nature is fascinating to watch. Some of the most mesmerizing fliers are butterflies. With their erratic twists, turns and dips, their flight pattern may appear downright whimsical. However, it is far from random. Consider how precisely one can locate and land on a flower or evade a persistent butterfly net. There are many very intricately connected muscles that allow butterflies to do this. The physics behind flight in insects, especially butterflies, is just beginning to be understood thanks to the use of high speed cameras and other research techniques.

Members of the "Insect Flight Group" at the University of Oxford trained red admiral butterflies to fly toward a fake flower in a smoke filled wind tunnel and used a high speed camera to view how the butterflies' wings move and push on the air around them. Other researchers are building working models of insects, especially dragonflies that can fly on their own. As important as active flying is, it isn't the only tool monarch butterflies use to get around.

Monarch butterflies can travel approximately 80-90 kilometers (50-55 miles) per day during their migration. This trip is only possible because monarchs are expert gliders; they can sustain periods of flight without actually flapping their wings or using energy. They are one of the few insects that can glide so effectively. This allows them to take advantage of thermals (updrafts of warm air) and favorable winds, limit damage to their wings and conserves energy. Observing gliding flight in birds and insects led humans to invent ways to glide themselves, using aircraft similar to airplanes but without engines. In fact, some glider pilots have reported seeing migrating monarchs gliding

Grades: 3-6

Key Concepts:

- Monarchs use both powered flight (flapping wings) and gliding as they migrate.
- Powered flight is more energy intensive than gliding, so monarchs take advantage of favorable wind conditions that allow gliding whenever possible.
- A paper glider can be used to illustrate features that make gliding both possible and more efficient.

Skills:

- Following directions and modifying design based on trials
- Data collection and analysis

Materials:

- Butterfly glider pattern (template and directions provided)
- Stiff paper for each student (old file folders work well, or construction paper)
- Metric tape measure or meter stick
- Butterfly Glider Data Table (student handout page)
- Scissors
- Glue
- Tape
- Graph paper (or computer if desired)
- Ruler
- 2 pennies per glider
- For student-designed gliders, provide additional paper of varying weight and stiffness; small paperclips, wax, play dough or other substances for weight

among kettles (circling flocks) of hawks at heights near 1,500 meters (about 5,000 feet) above the ground!

In this lesson students will experiment with paper glider designs that mimic the monarchs' shape and the angle of their wings when gliding. If possible, students should go outside during the monarch migration to view their gliding patterns. Have the students concentrate on the angles of the wings so they can work at reproducing these angles. If it is not feasible for students to observe migrating monarchs outside, they could observe monarchs they raise and release.

At first, students should use the design that we provide. They can then try to modify and improve this design to increase flight distances. Their goal should be to make the champion butterfly glider — the one that can glide the longest distance when released from the top bleacher in the gym or when thrown outdoors on a calm day.

Procedure

1. Form teams of four and explain the following duties:
 - Thrower throws the glider
 - Recorder writes results on data table
 - Spotter marks the landing
 - Measurer measures flight distance
2. Have students construct their gliders, following directions provided. Be sure they write their names on the glider wings.
3. Go to launch site where starting lines are laid out for each group. Allow enough room between groups to prevent in-air crashes.
4. Students should take turns launching their glider so they each launch five times for a group total of 20 launches. Each Thrower should complete all of her/his flights before switching duties. The number of throws per student can be adjusted to fit your time frame. Before they start recording data, each student should take a few practice flights.
5. After all group flights have been recorded, have each group determine the average flight distance for each glider separately and then for the entire group.
6. Have students construct a bar graph illustrating the average flight distance in comparison with others in their group.
7. Discuss the following questions:
 - What variables affected the distance your glider traveled?
 - Would this distance be increased if gliders were launched from greater heights? (You may want to test this experimentally.)
 - How could you modify your glider to improve its efficiency?
8. Encourage students to compare their gliders to real monarchs that they see, concentrating on the angles of both the front and rear monarch wings. Discuss the factors that affect the efficiency of the monarchs' glide. Are all of them reproducible in paper gliders? Discuss factors such as body shape and weight, subtle

adjustment capabilities and surface factors, especially the scales. Point out that only butterflies and moths have scales on their wings and discuss how scales might increase gliding efficiency. Discuss the effects that gravity, thermals (upward movement of warm air) and wind might have on monarchs.

9. Optional: Have students improve the design that is provided and hold a competition in the gym with their models. They can experiment by varying the height from which they launch their gliders and the force they use to launch the gliders.

Butterfly Glider Data Table

Name _____

Directions: Record the travel distances of all the gliders in your group.

Launch #	Student 1	Student 2	Student 3	Student 4
1				
2				
3				
4				
5				

Average _____

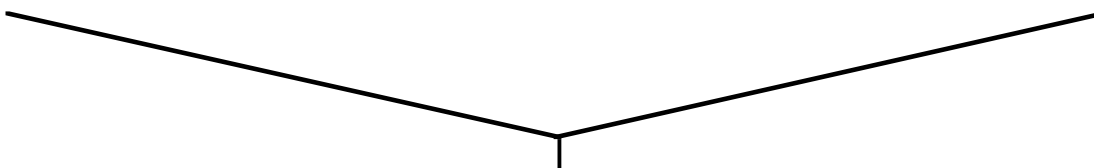
1. Try varying the height from which you launch your glider. How does this affect the distance your glider flies?

2. What happens to your glider if you throw it harder?

Directions for Butterfly Glider

Construction

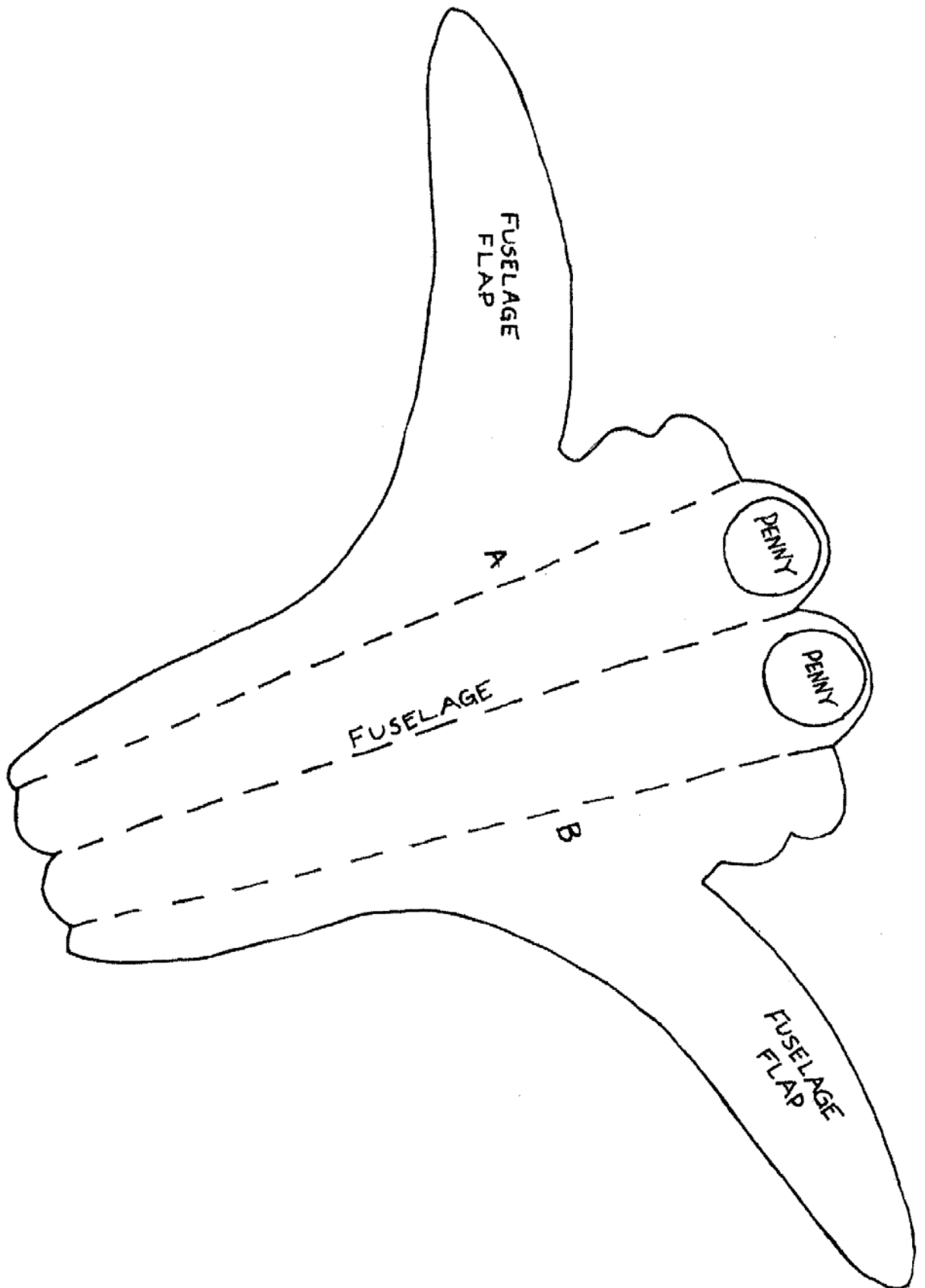
1. Trace body/wing and fuselage templates (see patterns) onto stiff paper and cut them out.
2. Fold fuselage on all creases. Fold center crease of fuselage section so that flaps point up, then fold outside creases A and B down.
3. Place a penny on each side of fuselage front and tape them in place. This should also seal the front of fuselage.
4. Cover the entire top of both fuselage flaps with rubber cement.
5. Align the fuselage with body/wing section and press together.
6. Allow glue to dry.
7. Crease body/wing section to form a dihedral:

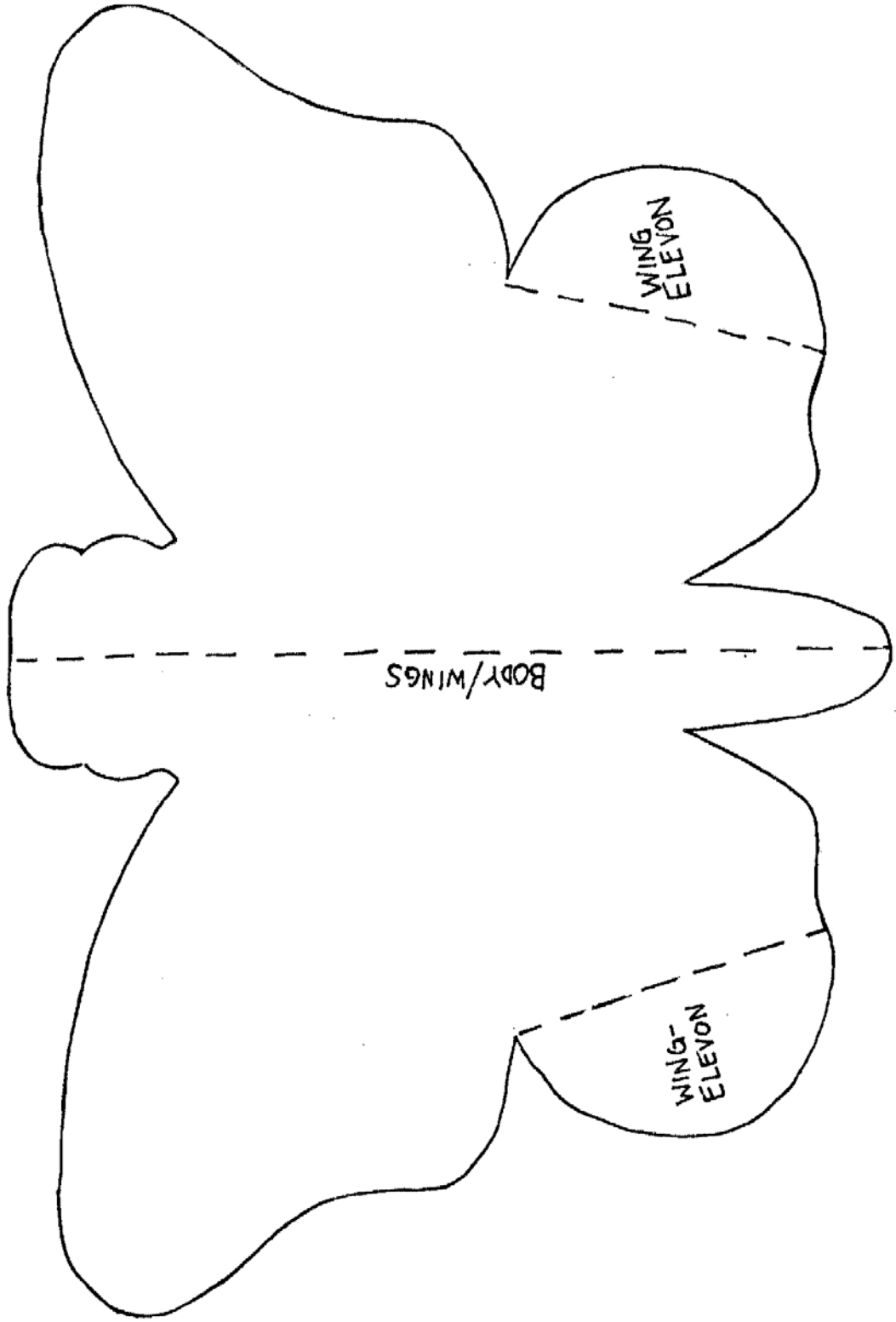


8. Crease wing elevons to an upward position.

Launching

1. Hold front area of fuselage between thumb and index finger.
2. Throw with a firm toss.
3. Adjust creases between flights, if necessary.





Insect Metamorphosis – A Bug’s Life

Objective

In Part 1, students draw (or build models) of their own invented insect, using the characteristics of insects as their guide.

In Part 2, students study examples of various insect life cycles and define incomplete and complete metamorphosis.

They then decide whether their insect grows through complete metamorphosis or incomplete metamorphosis and illustrate the stages of this insect’s life cycle accordingly.

Background

Almost all insects, and many other invertebrates and vertebrates (like frogs), undergo metamorphosis as individuals develop. There are two general kinds of metamorphosis for insects – complete (complex) and incomplete (simple). In either case, no insect can reproduce until it is in its adult stage.

Complete metamorphosis includes 4 distinct stages – egg, larva/caterpillar, pupa and adult. Insects that undergo complete metamorphosis include butterflies and moths (*Lepidoptera*), bees/wasps/ants (*Hymenoptera*), flies (*Diptera*), beetles (*Coleoptera*) and others.

Once the egg hatches, the larva spends all of its energy eating and avoiding being eaten. The larvae grow to a maximum size at which point they must produce a new skin and shed their old skin. The stages that are produced between molts are called *instars*.

Depending on the kind of insect they are, larvae are known more specifically as caterpillars (butterflies and moths), grubs (beetles) or maggots (flies). Most of these insects have evolved to have larvae that are either well camouflaged, bad tasting or can hide well in small cracks and crevices.

Grades: 3-6

Key Concepts:

- Insects are animals that scientists have organized as a group because they all have common features.
- Most insects go through metamorphosis as they grow.
- Some insects grow via incomplete metamorphosis (simple).
- Some insects grow via complete metamorphosis (complex).

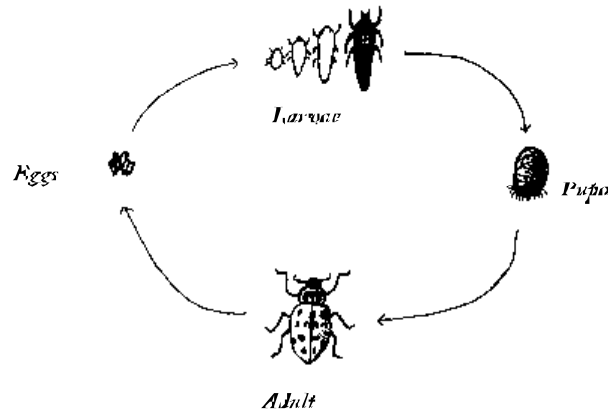
Skills:

- Think creatively
- Apply prior knowledge
- Make observations

Materials:

- Pictures of life cycle of insects with incomplete metamorphosis – at least three different life cycles, such as dragon fly, grasshopper, milkweed bug
 - Pictures of insects with complete metamorphosis –at least three different species such as a sphinx moth, ladybug, honey bee
 - Drawing paper
 - Crayons, colored pencils, pens
- Optional:*
- Miscellaneous “junk” objects
 - Pipe cleaners
 - Paper tubes
 - Egg cartons
 - Paper scraps

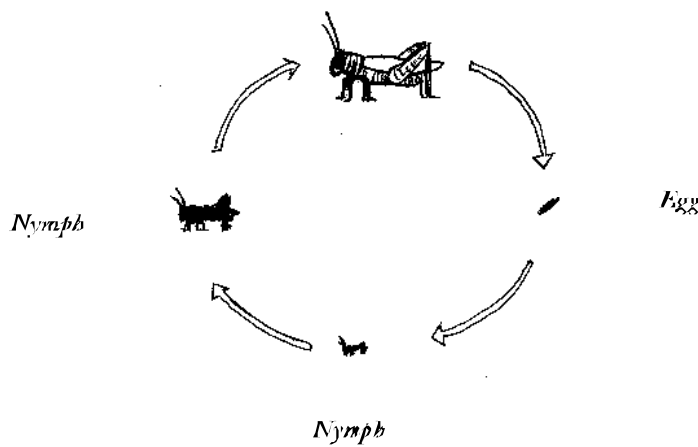
The Ladybug Life Cycle



From the larval stage, all insects in this group grow into a pupa of some kind (chrysalis, cocoon, pupa). It is from the pupa that they will emerge as a fully formed adult.

Incomplete metamorphosis includes 3 distinct stages – egg, nymph and adult (in aquatic species, the nymph stage is called a naiad). For these organisms, there is no pupa stage. After the egg hatches, the nymph slowly changes, molting between stages called instars, as it grows too large for its exoskeleton. With each molt, the size and form of the nymph change slightly but throughout the process closely resembles the adult form it will eventually become. Some orders that undergo incomplete metamorphosis include true bugs (*Hemiptera*), grasshoppers/crickets/katydid (*Orthoptera*) and cockroaches (*Blattodea*).

The Cricket Life Cycle



Procedure

Part I

1. Begin by reviewing the definition of an insect. List the following common physical traits of insects:

- Head, thorax and abdomen (3 distinct body parts)
- Three pairs of jointed legs

- Hard exoskeleton
 - Two compound eyes as adults
 - Wings and antennae (common but not required)
 - No more than four wings
2. Ask students to spend some time sketching their own “new” insect species. When they come up with one they really like, ask students to “test” their insect to make sure it has everything on the list you created.
 3. Partner students who are finished drawing with one another to “test” each other’s insects by using the list.
 4. If desired, after students get their insect approved by a peer and by you, have them re-draw their insect on a piece of drawing paper you provide. Model for students how to use their whole paper or insect features will be too small for others to see.
 5. Students should name their new species of insect.

Part 2

1. Assign students to groups of three. Distribute life cycle samples to each group, making sure to include at least one example of both complete and incomplete metamorphosis in each group. Do not point out the difference to the students.
2. Ask students to study the life cycle pictures. Ask students what they notice about insect life cycles. Ask “*What is true of all the life cycles you are looking at?*” Similarities include:

- All begin with an egg
- All show change over time
- All end with an adult insect

Now ask “*What’s different among the pictures you’re looking at?*” Differences include:

- Some show a larva (or caterpillar or maggot) – correct students if they use the term “worm”
- Some show smaller versions of the adult getting bigger over time
- Some show a pupa, but others don’t (students might not know what to call this stage, so use this opportunity to teach the term pupa)

3. Tell students that they have just discovered the two types of insect life cycles. Introduce the terms *complete* and *incomplete metamorphosis* and write them on the board. Explain that all insects undergo

one or the other. Monarchs, beetles, wasps, ants and flies are all examples of complete metamorphosis. “True bugs,” like milkweed bugs, stink bugs and boxelder bugs undergo incomplete metamorphosis, as do grasshoppers, crickets, dragonflies, mantids, walking sticks, and cockroaches.

Next, ask students to bring up their pictures and place them into the correct category of metamorphosis.

Finally, discuss why scientists have called these two life cycles using the terms complete and incomplete.

“What is complete about a monarch’s life cycle?” “What is incomplete about a cricket’s?” This will help them remember the terms.

4. When students have seen enough examples, create a list or poster to define each of the two kinds of metamorphosis.
5. Ask students to choose which kind of metamorphosis their invented insect uses and to illustrate each of the appropriate stages. If they choose incomplete metamorphosis, they should decide how many instars their nymphs go through. If complete, how many instars do their larvae go through and what does their pupa look like?
6. As students finish their illustrations, display their invented insect along with its life cycle. You might sort the inventions according to the type of metamorphosis each uses.

Alternative

Instead of making final drafts of their insects as a drawing, students might build their insect out of recyclables and other materials you provide. Insects could be hung in your classroom. If time allows, students might also create the other stages of their insects’ life cycles and display them as a mobile.

The Very Hungry Caterpillar

Objective

Students will first predict and then estimate how much milkweed a larva consumes on a daily basis. If the research is carried over several days, they will learn how much milkweed consumption varies with larval age and size.

Background

Start the lesson a day or so after you obtain the larvae. Part 1 should be done on the first day, and Part 2 starts the second day of the lesson and can be repeated daily until larvae pupate, if desired. You should use an individual container for each larva. Larvae can be kept in clear plastic cups with lids for several days without harm. Be sure to punch holes in the lids to allow airflow.

This lesson will not work with late fifth instar larvae (i.e. those that are about to form a chrysalis), since they stop eating at that time. Also, when larvae are molting (shedding their skin), they often stop eating for a day. This will be interesting for students to observe. Modify this lesson if there is not one larva per pupil.

You can pick enough milkweed for several days and keep the stems in jars of water or plastic bags in the refrigerator.

Procedure

Part 1—Planning and Setting Up the Experiment

1. Ask students if they have read *The Very Hungry Caterpillar* by Eric Carle. You may wish to read it to them at this time and ask the following questions:

- *Why do you suppose Carle chose a caterpillar as his subject?*
- *Would another animal subject have worked as well?*
- *What do monarch larvae eat?*
- *How can you tell how much they have eaten since the last time you observed them?*

Grades: 3-6

Key Concepts:

- Monarch larvae consume large quantities of milkweed each day.
- The amount of milkweed a larva consumes depends on its age and whether it is molting.
- The amount of milkweed a larva consumes can be estimated in many ways.

Skills:

- Observation
- Prediction
- Measurement
- Data recording
- Data reporting
- Estimation
- Use of percent

Materials:

- Monarch larvae
- 10+ oz. plastic cups (one for each larva)
- Milkweed (at least one large leaf per larva per day)
- Triple beam balances (or electronic scale, if you are lucky enough to have one)
- One Data Organizer: Hungry Caterpillars for each student, pair, or group (student handout page)
- Plastic wrap or Petri dishes

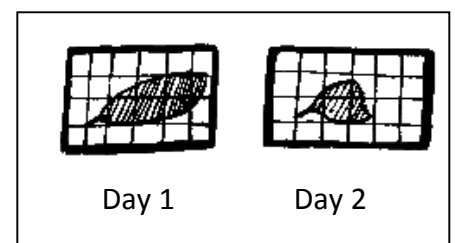
2. Ask your students:

- *How could you measure the amount of milkweed your caterpillar eats during a day?*
- *During 24 hours?*
- *During a week?*

3. On the board, list students' ideas for measuring how much a larva eats. If it is suggested, you could use the method described here. You may also opt to use one of the other methods students suggest or allow groups to pursue different methods.
4. Divide the class into small groups and assign roles. Ask the Getters to come up and get the larvae for their group, one piece of milkweed for each larva, and a *Data Organizer: Hungry Caterpillars* for each student.
5. Each student should trace the milkweed leaf on the grid of the *Data Organizer: Hungry Caterpillars*. Count the number of squares within that leaf shape. Discuss strategies for counting partial squares. Place the milkweed and larva in the empty, clean container. Cover with a Petri dish or plastic wrap. Assure the students that there will be enough oxygen for the larvae to breathe for one day.
6. Students should estimate how much their larva will eat in squares or as a percent of the whole leaf, i.e., "*How many squares of leaf will your larva eat by ____ (time) tomorrow?*" Have students describe their testing procedure (what they will do to measure how much the larva will eat). Record the surface area of the leaf tracing in squares. Students may draw illustrations of their procedure.
7. Large larvae should get two leaves. Place the cups out of direct sunlight and away from other heat sources. If the room is dry, add a damp piece of paper towel or filter paper. Be sure to clean the paper every day, and replace it every few days to prevent mold.

Part 2—Doing the experiment and analyzing data

1. Remind students what question they are trying to answer from the last lesson: *How much food does one monarch larva eat in a given period of time?* Have them look at their data sheets to see what predictions they made. Decide how you would like to have your students compare their predictions to their results.
2. Ask Getters to get the larvae for their table. Instruct students to get their log books and the *Data Organizer: Hungry Caterpillars* sheet.
3. Set the eaten leaf directly over its tracing on the *Data Organizer: Hungry Caterpillars*. Students should trace around the eaten portions of the milkweed leaf. If the leaf is wilted, this must be done with care and patience. When they are finished tracing, students need to count the number of squares that were eaten, using the same strategies they used in Part 1.
4. Have students compare their estimate with their actual square units of milkweed eaten. Then students can calculate the percentage of the total milkweed that the larva ate:
$$(\text{Number squares eaten} \div \text{total number of squares in the leaf}) \times 100 = \% \text{ eaten}$$
5. As a class, find the average amount of milkweed a monarch larva eats within the time frame you chose. You might average the number of squares or the percentages. Before doing this, list the data on the overhead



and ask students to estimate the average. Determine if this varies with larva size or other factors, such as whether they were molting.

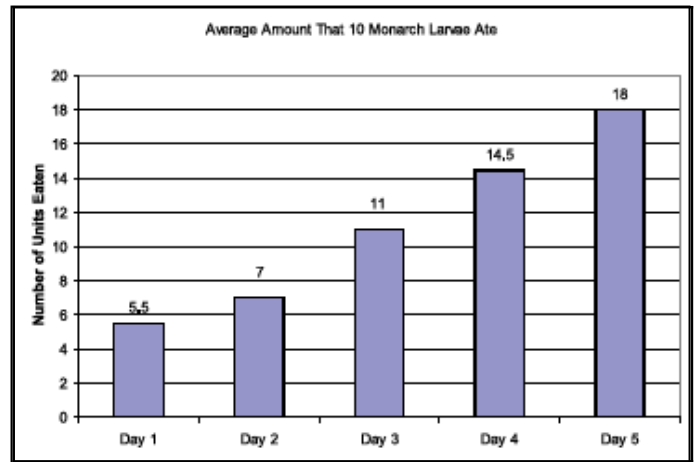
6. Assess student understanding by giving them a leaf tracing on graph paper with an area outlined to represent the amount that a certain larva ate during a 24-hour period. Ask them to estimate the amount eaten, then count the actual amount eaten in square units. You might ask them to calculate the percentage eaten, if an understanding of percentage is a desired outcome.

7. If desired, have students graph the results over several days as a class or in small groups. You can use averages or make a separate graph for each larva.

8. Students often ask whether larvae eat at night. You may repeat this activity, measuring what was eaten during the day and night (from the time school ends to the next morning). Compare these amounts.

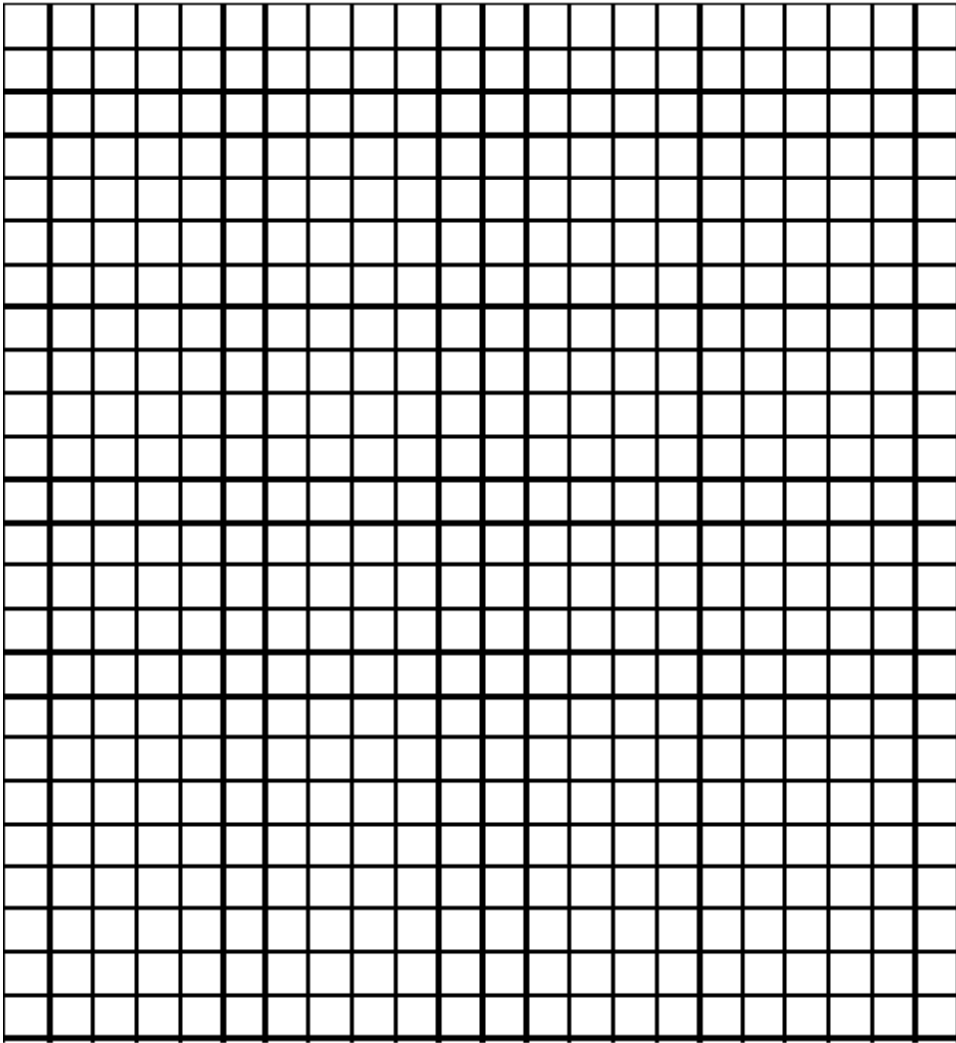
9. Modification: To make this lesson easier for young students, enlarge the graph paper on the student handout.

WHAT DOES THIS LOOK LIKE?



Data Organizer: Hungry Caterpillars

Name _____



Part 1

1. Estimate the size of your leaf – _____ squares
2. Trace the leaf. The surface area = _____ squares
3. Predict the amount of leaf your larva will eat – _____ squares
4. Predict the percentage of leaf your larva will eat – _____ %

Part 2 (the next day)

5. Trace the leaf area eaten by your larva

6. Count the number of units eaten – _____ squares

7. Calculate the percent of leaf eaten (squares eaten \div total squares in leaf) X 100 – _____%

Warning Coloration

Objective

Students will learn about warning coloration and create an artistic rendition of an organism with warning colors.

Background

Warning (or Aposematic) Coloration – Many poisonous or distasteful organisms are brightly colored, usually with some combination of red, orange, yellow and white. Predators learn to associate these colors with animals that they should avoid eating.

Procedure

1. Ask students if they think that bright colors could ever protect butterflies or moths from predators. They may not come up with the idea of warning coloration. Show them a “Mr. Yuck” symbol or a skull and crossbones label on a container of a poisonous substance and ask them if they know what it means. They have probably learned to associate the label with many kinds of poisonous things.
2. Tell your students that many butterflies are poisonous and advertise this with bright colors and bold patterns. Predators learn to leave brightly-colored butterflies, and other animals, alone.
3. Compare bright patterns on toxic butterflies and moths with the colors and patterns found in symbols people use, like red and white stop signs and bright orange triangles on slow vehicles. These are brightly colored so that people can easily learn to recognize them.
4. Other toxic animals, such as frogs, have bright patterns. The bold pattern on skunks is another example of warning coloration; this pattern makes it easier for an animal to learn to avoid skunks after being sprayed by one. Show students pictures of these animals.
5. Have students create and draw a fantasy animal with warning coloration. They should name their animal and tell what defense it has against predators.

Grades: 3-6

Key Concepts:

- Bright colors can serve as a warning to potential predators that an organism is toxic.

Skills:

- Interpretation of information
- Art

Materials:

- Pictures of brightly colored, toxic frogs (see books on rainforests) and skunks
- Optional: pictures of warning signs (like stop sign, slow vehicle sign, etc.)
- Optional: bottle with poison label
- Art supplies for student

You Don't Taste the Way You Look:

Understanding Mimicry

Objective

Students will be able to explain types of mimicry, its survival advantage and relate Mullerian mimicry to populations of butterflies that may include monarchs and viceroys.

Background

Mimicry is one of several anti-predatory devices found in nature, in which one species called the mimic resembles the color, form and/or behavior of another species. In so doing, the mimic acquires some survival advantage.

There are 2 basic forms of mimicry:

1. Batesian – the mimic (palatable) resembles the other species (unpalatable) and only the mimic benefits
2. Mullerian – both species are unpalatable and both benefit

Mimicry provides potential survival value, especially to species whose populations are threatened. Mimicry, as opposed to camouflage and warning coloration, is specifically the resemblance between two organisms. The same techniques of deception are sometimes utilized in all three anti-predatory devices. These include variations in color, pattern and structure. The viceroy closely resembles the monarch and until recently people thought that it was a harmless mimic of the toxic monarch. However recent studies have shown that it is actually slightly toxic to some predators, so it is a good example of a Mullerian mimic.

Procedure

1. The teacher will need to prepare the unpleasant materials ahead of time to allow for drying.
 - Choose two colors that most closely match to represent the mimic and model species and alter their taste by placing in an unpleasant substance such as lemon juice extract.
 - This will represent the species and the closely matching color the mimic.
2. On the day of the activity, spread them on a clean tray or table top in a random fashion. Have students record the number of each different colored 'prey' at the beginning of the activity.

Grade: 3-6, 7-12

Key Concepts:

Mimicry is a form of camouflage that in the case of Mullerian mimicry benefits (protects) both species
Predator/prey relationships

Skills:

Making observations
Drawing conclusions from data
Math (tables and graphing)

Materials:

150-200 each of one or more of the following: Fruit Loops, Whole Grain Cheerios, Gummy Savers.
Concentrated lemon juice/extract

3. Explain that this activity is designed to simulate mimicry in nature and that the students will be predators.
4. Have students come to the prey table and select any item of their choice (but do not eat it yet) and return with it to their seat.
5. After all the students have returned to their seats, they can eat the piece selected. The students should not reveal any aspect of what they experienced/tasted.
6. Repeat steps 4 and 5 several more rounds.
7. Record colors and numbers of different “prey” remaining.
8. Have students create tables or graphs to represent their results.
9. Have students answer/discuss some of the following questions;
 - What colors remain and in what proportion?
 - How might this exercise relate to organisms in nature?
 - What method of evading predators does this activity illustrate?
 - Give examples from nature that this activity simulated.

Flight of the Butterflies

(Film logo)

Classroom Activities

Grades 7-12

Schoolyard Phenology

Objective

Students will keep a record of their local phenology (seasonal changes and their effects on nature) by recording data in class charts and/or individual journals. The charts are a collaborative and visible record of seasonal events and the date observed. The journal is a venue for students to record observations, drawings and interpretations of seasonal events. Both charts and journals will serve to prompt conversation about and engagement with the schoolyard environment.

Background

Phenology is an account of seasonal changes and the effects on plants and animals in a given location and the biological effects of those changes. In this lesson students will observe and record the seasonal occurrences of weather, plants and wildlife in the familiar surroundings of their schoolyard. Through consistent observation and data collection students will increase their awareness of nature.

In the second part of this data collection exercise, students will learn to keep detailed weather records during the fall monarch migration. Having a class record of weather data will provide opportunities for graphing and data analysis activities, while it advances our understanding of monarch behavior.

Procedure

Part 1

1. Introduction:

Ask students if they notice any evidence that the seasons are changing. Introduce the word *phenology* and give a few examples, such as the first freeze in the fall or the first monarch butterfly in the spring. Then ask students for more examples. Ask students to share ideas about why it might be important to understand seasonal weather changes and the ways that plants and animals respond to them.

Grade: 7-12

Key Concepts:

- Seasonal change in our climate can be seen in subtle ways.
- Some annual climate changes are indicated by changes in physiology and behavior of animals.
- We can observe and predict changes in our natural world and monitor its health by noticing these indicators.

Skills:

- Make observations and record data
- Make predictions
- Determine consequences of seasonal events

Materials:

- Phenology Charts (teacher page)
- Student journals/notebooks
- Rain and snow gauge
- Weather data website
- Optional: Anemometer (to measure wind speed, if not available wind speed can be estimated)
- Compass (to measure wind direction)
- Thermometer (if possible, a max/min type)
- Daily Weather Observations Data Sheet (student handout sheet)

Through discussion, help students understand that phenology can provide a means of monitoring the impacts of climate patterns. An example is the relationship of weather to the success of an agricultural crop on which humans depend for income and food. Apples require above-freezing temperatures in the spring to maintain the flower bud development. There are concerns that seasonal patterns, and the plants and animals that depend on these patterns, may be changing as a result of global climate change.

2. Use the Daily Phenology Log to keep track of important weather and other natural events.

- **Phenology charts:** Display phenology charts in the classroom. The chart can be a copy of the list below (phenology chart) or events can be divided into smaller categories. You can observe them all or choose a few. Have students record their predictions and the date. This can be done on a classroom wall or in individual journals. All events that are “firsts” will have only one date. Events that are “peak” or “last” will have a number of dates until the true “last” or “peak” is revealed, such as the last rain in the fall.

Incorporate incentives for students to participate. Perhaps assign specific events to individual students whose job it is to observe a particular seasonal event and record it on the class list. You can use the chart below or design your own to be a larger and more visible part of your classroom. Use the blank spaces to add observations appropriate to your location. On a weekly basis, discuss the relevance of the events and observations as a class.

- **Rain and Snow Chart:** Keep track of the total accumulation of rain and snow by recording the daily measurable amounts on a vertical meter on the wall. At the beginning of the year have students predict how many inches of rain and snow will fall during the school year and compare their predictions with the results from the class chart at the end of the year. For this chart, students will either measure the rainfall and snowfall or take the measurements from the newspaper. Each addition will be recorded to a growing column up the wall.
- **Open Forum on Phenology:** Provide a time or place for students to share their weekly phenology observations. A large sheet of butcher paper can be pinned up for students to write or draw upon to share their wildlife and weather sightings. Or provide time each week for students to tell the class about their observations.
- **Individual journals:** Have students predict and keep track of seasonal events in their journals. Use the chart included or modify them. Another suggestion is to assign a student or a pair of students to observe a plant or space of land over the seasons. Allow students 15 minutes to observe and record their observations and questions about their plant or space of land at regular intervals throughout the year.

Part 2: Weather During the Spring and Fall Migrations

1. Discuss the importance of long-term weather data with your students. Tell them that weather records dating back over a hundred years are maintained for many locations throughout the world and discuss why this is useful. They will probably mention that weather records help in predicting the weather. However, biologists can use weather records to help understand patterns in the natural world. This will be how your students use the data they collect in this lesson.
2. It is best if students actually collect weather data themselves. This can be done at school; assign the task to individual students. If students do not collect the weather data, they can get it from sources such as newspapers, TV or the Internet.

3. Set up a time and location to collect weather data. Wind and cloud cover records should be taken at the same time each day. If you do not have an anemometer, estimate wind speed as strong, breezy, light or calm. Cloud cover can be clear, partly cloudy, mostly cloudy or overcast. If possible, get a high and low temperature for each day. Use a rain gauge placed in a location where it will not be disturbed or affected by trees, bushes or roof overhangs.
4. The amount of time over which you record weather data is up to you. If you live in the southern part of the country, there may be monarchs in your area as early as March or April and as late as November or December, or even throughout the entire winter, and you could keep track of the weather during this time. If you live in the north, you may want to start recording weather conditions right at the beginning of the school year for fall migration and as soon as migrants are reported in the south for spring migration. Students could then compare conditions in their location to those where monarchs are being seen.
5. Have students analyze their weather data in some way. They can graph temperature over time, cumulative rainfall, the percentage of days with different amounts of cloud cover or anything else they can think of. You may want to have each student choose something to analyze. They should come up with a specific question (e.g., How does the spread between daily high and low temperatures vary during the month of September?), choose the data they need to answer the question and make a graph that will best show the answer to that question.

Application to Monarchs

1. There are many ways to relate weather conditions to monarchs and their host plant, the milkweed.

Questions to consider include:

Fall

- What are the conditions after you stop seeing monarchs?
- When is the first freeze?
- How does very cold weather affect the chances of monarchs surviving and being able to migrate?
- What happens to flowers in your area after it freezes?
- What happens to milkweed after it freezes?

Spring

- What are the conditions when monarchs are first seen in your area?
- When is the last freeze?
- What are the conditions when the first milkweed appears?
- How does the growth rate of the milkweed vary under different temperatures and precipitation levels?

Daily Phenology Log

Name:

Location:

Date:

Time:

Sky:

Daily High Temperature:

Daily Low Temperature:
(including night time)

Precipitation type:

Precipitation amount:

New observations:

Updates on previous observations:

Questions:

Drawings:

Rearing Monarch Larvae

Objective

To further students' knowledge of the monarch life cycle as they raise Monarchs in the classroom or at home.

Background

There are many ways to organize monarch rearing in your classroom. A class can work together to rear their larvae, or individual students or groups of students can be responsible for their larvae. You may even want to have students rear their larvae at home, thus involving their families.

If your students are caring for monarch larvae, or any other living organisms, it is very important to take time to teach them how to do this. Larvae need to be fed, and their cages need to be cleaned *daily*. Students can be responsible for this, and take larvae home on weekends. (Make sure bus drivers allow larvae on the bus. They don't in some school districts.)

As larvae develop and their metamorphosis into adult butterflies progresses, you may want to demonstrate other techniques, such as how to move a chrysalis and hold, feed and measure adult butterflies. This lesson only covers the actual process of rearing. As your students rear larvae, they will learn more if they measure growth and development, and keep journals to record their detailed observations. You can also use the larvae to teach about conducting scientific experiments.

Procedure

1. Discuss requirements for the larvae: e.g. food, clean container, proper temperature. If students will be responsible for collecting milkweed, do steps 2-3. Otherwise, skip to 4.
2. Display pictures or samples of various milkweed plants and tell students what kinds of milkweed are most common in your area. Ask students where they have seen milkweed. (You may want to display a map of the area so that specific sites can be highlighted.) If it is impractical for all students to collect milkweed, this can be the responsibility of a few students or the teacher.
3. List three distinguishable features of the most common milkweed in your area on white boards/poster paper (for example: common milkweed has opposite leaves, secretes a sticky white substance when the leaves or stem are broken, has long oval-shaped leaves).

Grade: 7-12

Key Concepts:

- Rearing monarchs requires daily care and effort.
- Monarchs require fresh milkweed and a clean environment at all times.

Skills:

- Rearing technique for monarch butterflies

Materials:

- Monarch eggs or larvae in appropriate containers for students to use in rearing milkweed plants or cuttings for demonstration
- Background information on milkweed

4. Keep track of larval growth and development. If desired, have students keep journals during this process. Use other resources to learn about the body parts of each stage and how the monarch is changing during the different stages.
5. When their larvae have completed the entire development, have students demonstrate their knowledge of the monarch life cycle and body parts. You may choose many methods to do this. For example, students could work individually or in pairs to make a poster, a slide show, a viewing box, a 3D model or something else of their choosing. All projects should include the following:
 - *The four life cycle stages with labels*
 - *The main parts of the larva*
 - *The length of time each stage lasts*
 - *The main parts of the adult*
 - *The host plant*
 - *A list of requirements and roles of each stage*

Monarchs in the Balance Dilemma Cards

Objective

Students use their knowledge of monarch overwintering habitat in Mexico to debate issues of land use from a variety of perspectives represented on dilemma cards. They compare conservation issues of monarch habitat in Mexico with those across the U.S. and Canada.

Background

This lesson will help students understand the complex issues that involve the overwintering sanctuaries in Mexico. It assumes students have an understanding of monarch migration and some of the conservation issues connected with the overwintering sites.

Students will read six Dilemma Cards that represent several different groups of people with interests in the monarch overwintering sites. There are no “right” solutions to these dilemmas. Their purpose is to make students think about all sides of the tough issues surrounding monarch conservation in particular and human/animal/plant/ecosystem interactions in general.

We have suggested two different ways to use the dilemma cards. In the first, students discuss the dilemmas in small groups, then summarize with a class discussion. In the second, students discuss the dilemmas as a class and then do individual writing activities to summarize the perspective of a person described on one of the cards.

Procedure

1. See the film **Flight of the Butterflies**, show photos from books or the *Monarchs in the Classroom* CD or slides to help students get a picture of what monarch wintering habitat looks like and have students read the background on monarch migration or other materials.
2. Discuss the issues involved with conservation of the overwintering sites with your class.
 - *What is at stake?*

Grade: 7-12

Key Concepts:

- Organisms throughout the world are in competition for resources.
- Humans through the world use natural resources to survive.
- Human behaviors affect resources that many organisms rely on.
- Humans rely on an economy, an exchange of goods and services, in order to survive.

Skills:

- Identify stakeholders in a community
- Describe a variety of perspectives
- Brainstorm solutions

Materials:

- Dilemma cards (student pages) cut apart and mounted on tagboard or construction paper. For the first activity, you will need one complete set for each group of 4-6 students. For the second, each student will need one dilemma card.
- For the second activity, one *Monarch Dilemma Student Page* per student (student handout)

- *Why are the sites so important to monarchs?*
- *What are the conflicts between different uses of the land?*
- *How might different groups of people be concerned about actions that affect the sanctuaries: rural peasants, farmers, townspeople, Mexican government officials, biologists, conservationists, lumber companies and students?*

Activity 1: Small Group Discussion

1. Give groups of 4-6 students a stack of the six dilemma cards.
2. Students place the cards face down in the center of the table and all draw a card at once. Each student should take a few minutes to read the dilemma silently and choose a course of action (2 minutes).
3. When the students are ready, have them take turns reading their dilemma to the rest of the group and explaining their decision and reasoning.
4. The other students in the group comment and share their opinions.
5. The card is returned to the center of the pile, and the next student takes a turn.
6. When all dilemma cards are discussed, students share and discuss their different perspectives.
7. Discuss the following questions with the whole class. If desired, have students write answers to the questions individually or in their groups:
 - *Which was the toughest dilemma and why?*
 - *If you could be a person in the dilemma, who would you pick and why?*
 - *What are the key issues in monarch conservation?*

Activity 2: Class Discussion and Individual Writing Assignment

1. Briefly describe each of the people represented in the dilemma cards. Tell students that they will each receive one of these dilemmas and write a letter as if they were this person.
2. Hand out one card and the *Monarch Dilemma Student Assignment Page* to each student. Have them first list reasons to preserve monarch sanctuaries and then problems with maintaining the sanctuaries.
3. Have students write a letter, staying in character for the whole letter.
4. Optional: Choose one or a few of the following follow-up activities:
 - Have students read their letters in class.
 - Organize a debate in which students express the issues that concern their characters.
 - Have students write letters expressing their personal views on the issues.

Monarch Dilemma Student Assignment

Name _____

1. List 3-5 reasons why monarch overwintering sanctuaries are important.

2. List 3-5 problems with maintaining monarch overwintering sanctuaries.

3. You will receive a card that describes one person's perspective on the monarch overwintering colonies in Mexico. Write a letter as though you are the person on the card. Decide who will receive the letter: a government official, a friend, a conservation organization or someone else.

Include the following ingredients in your letter:

- Describe who you are and your situation.
- What do you think you or other people should do about the problems described in your dilemma card? Please be as specific as possible. For example, if you would like to find another way to support your family, suggest a specific idea. If you are going to increase tourism, list a few ideas about how you plan to do this.
- What are positive consequences of your choice?
- What are negative consequences of your choice?
- Include a closure that summarizes your point of view.

DILEMMA CARD 1

You are an *ejidatario*, a local resident/landowner, who owns part of the forested land where the monarchs overwinter. You depend upon logging the forests for a cash income in order to buy food, clothing and other supplies for your family. Environmentalists have told you not to cut down any more trees because you are reducing the overwintering habitat for monarchs. Should you:

- Continue logging the forest?
- Find another way to support your family? What else could you do?
- Continue logging the forest but only cut down the very oldest trees (selective cutting)?
- Other better solutions?

DILEMMA CARD 2

You and your family won a trip to visit a monarch overwintering site. You buy delicious food – tortillas, quesadillas, tamales and tacos – from villagers who have set up food stands. In order to get to the monarch park, you pay \$3.00 to ride in the back of a pick-up truck up a bumpy dirt road. At the colony there is an admission fee of another \$2.00. You are told to stay on the paths and to not touch the butterflies – even the dead ones! Just to the side of the path you see what looks like a dead monarch with a tag on its wing. Should you:

- Pick up the butterfly and read the tag but leave it in the park?
- Leave the butterfly where it is but tell the park guide where you saw it?
- Pick up the butterfly and take it home so you'll have something special to remember the park with?
- Try to sell the butterfly to a park guide?
- Other better solutions?

DILEMMA CARD 3

You are a resident of a village near a little-known monarch colony high in the mountains called Valle de Bravo. Tourists seldom visit your village because it is difficult to find the path that winds up the mountain. Some villagers wish to develop tourism at this colony; they want to build a road cutting a clear path up the mountain, develop small shops to sell monarch trinkets and charge people money to guide them through the colony. You are concerned about the effects tourists and the road would have on the forest, the butterflies and life in your village. Should you:

- Support the villagers who wish to build the road and develop tourism?
- Oppose the road construction but support a plan to encourage visits by tourists who are willing to climb the steep path?
- Try to convince villagers not to encourage tourism?
- Other better solutions?

DILEMMA CARD 4

You are a scientist who has done research on monarchs in the colonies for the past 20 years. In addition, you have led groups of interested tourists into the overwintering colonies. It is your hope that tourism will replace logging as a source of income for the people in the villages. Unfortunately you have noticed that the dust stirred up by all of the tourists harms the butterflies. Should you:

- Stop encouraging tourists to visit the monarch sites?
- Decide that the money from tourism is worth harming a few butterflies?
- Work to find ways to keep dust levels low, even if this means less money for the people?
- Other better solutions?

DILEMMA CARD 5

You are a government official who is elected to represent the area in the state of Michoacan in Mexico, where monarchs overwinter. You have always been very concerned about conservation, but after your election you learn how poor the people are who live near the colonies and how bitter they are that they have never been compensated for the income they previously earned from logging the trees in these areas. They would like to log a limited number of trees in the sanctuaries. Should you:

- Tell them that the long-term survival of the monarchs is more important than short-term economic gains?
- Try to convince other government agencies to open some of the land for logging?
- Try to develop alternative means of income for the people? What will these be?
- Other better solutions?

DILEMMA CARD 6

You are Señor Sanchez, a 68 year old community leader living near Sierra Chincua where a very large colony of monarchs overwinters. You have worked for the conservation of monarch habitat for more than 30 years. Now you are bitter because you have a job planting trees paying a very small salary with no pension and a family to support. Members of the community are upset because you worked to close the mountain to logging. A friend who lives in the village begs you to help him carry out a tree he has cut and can sell for a large sum of money. Should you:

- Turn in your friend for poaching?
- Help your friend carry out the tree, but only this once?
- Ignore your friend and continue your work to preserve the monarch habitat?
- Other better solutions?

How Many Grandchildren?

Objective

Students will calculate the number of progeny that one female monarch butterfly could produce in one year (4 generations).

Background

Monarchs, like most insects, produce many small offspring, few of which are likely to survive to adulthood. Monarch parental care occurs when females lay their eggs; they only choose milkweed plants, preferring plants in good condition. However, when the larvae hatch, they are on their own. In this exercise, students will determine how many grand progeny a single female could produce, *if all of her offspring survived*.

When biologists study how populations grow, they only count the offspring from females. If they counted offspring from both sexes, their counts would be twice as large as they should be. For example, if a human family has two children, it would not be accurate to say that because the male has two children and the female has two children, there are four children. Thus, we will only count the offspring that the female's daughters (and their daughters) have.

Procedure

1. Discuss the fact that female monarchs lay an average of 700 eggs during their lifespan, while humans and elephants have few offspring. The purpose of this is to compare the number of offspring females of different species produce. Students may say that monarchs produce so many offspring because many of them won't survive. However, they can produce so many because each offspring is very small and receives no parental care.

2. Each egg weighs only about 0.45 mg, while a female weighs about 500 mg, so each egg is 0.0009% of the female's weight. This would be like a human female who weighs 130 pounds having a baby that weighs about one tenth of a pound (or less than two ounces)! If human females had two-ounce babies and didn't provide care for them, she could produce more babies, yet many would not survive. This illustrates two different strategies: *Have many small offspring that don't receive parental care or fewer bigger ones that receive parental care.*

3. Students who understand ratios can do the calculations themselves:

$$\begin{aligned} &0.45 \text{ mg} \times \text{lb} \\ &500 \text{ mg} \times 130 \text{ lb} \\ x &= \frac{(130 \text{ lb}) (0.45 \text{ mg})}{500 \text{ mg}} = 0.117 \text{ lb} \end{aligned}$$

Grade: 7-12

Key Concepts:

- Survival is usually low in organisms that produce large numbers of offspring and high in those that produce fewer offspring.
- If all monarchs survive, the world would soon be overrun by monarchs because of the large number of offspring they produce.

Skills:

- Reasoning
- Math (multiplication of large numbers)

Materials:

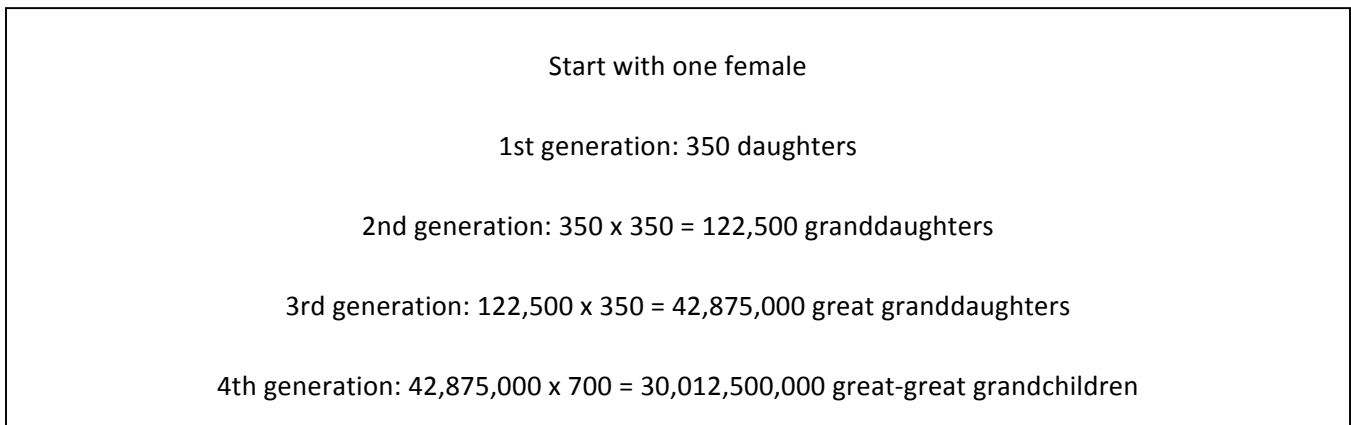
- Paper and pencil
- Calculator, if desired

4. Have students calculate how many grandchildren (from her daughters) one female could produce, if none of her progeny died and if half of her offspring were females. Younger students will have to be stepped through this calculation, but older students should be able to figure it out.

Answer: One female lays 700 eggs. On average, half of these eggs are females, so she has 350 daughters. If each of these daughters lays 700 eggs, the original females will have $350 \times 700 = 245,000$ grandchildren.

5. Optional: Tell students that monarchs can have up to four generations in the summer. Have them figure out how many great-great grandchildren the female would have, remembering that only half of each generation will be females laying eggs.

Answer: One female has 350 daughters. Each daughter produces 350 granddaughters, who each produce 350 great granddaughters, who each have 700 total offspring; $350 \times 350 \times 350 \times 700 = 30,012,500,000$ great-great grandchildren. This is more than the total number of butterflies that overwinter in Mexico each year. Clearly, all of these monarchs do not survive. It's helpful to illustrate with a diagram:



6. This lesson illustrates exponential growth, which is very fast. Compare the number of offspring after two generations to that after four generations. You may want to make a graph using these numbers, but it is difficult to do this when the numbers are so large.
7. If desired, use these calculations to discuss human population growth. Furthermore, discuss how environmental factors like space, food, water and disease could limit such fast growth. Try the calculation using two children in each generation, and then do it with four children. Compare the number of great-great grandchildren.
8. Note: Monarch eggs and caterpillars are an important food source for birds and other insects. Less than 1% survive to become butterflies.

Comparing Butterflies and Moths

Objective

Students learn the similarities and differences between butterflies and moths.

Background

Moths and butterflies are in the same insect order, *Lepidoptera*. The name of this order describes a characteristic that all Lepidoptera share: scale wings. Scales cover their wings and their bodies. Additionally, all *Lepidoptera* have four wings (a pair of forewings and a pair of hind wings), antennae and compound eyes. All undergo complete metamorphosis with larvae that molt as they develop. There is no distinct line of features to divide moths and butterflies, but in general the distinctions (and some exceptions) are these:

- Many moths build cocoons, using silk that they spin or bury their pupae in the ground for protection. Butterflies usually form a “naked” pupa, called a chrysalis. However, some skippers and Parnassian butterflies build rudimentary cocoons.
- Moths are generally active at night, while butterflies are active during the day. However, there are some brightly colored moths that are active during the day.
- Moths generally have subdued camouflaged colors, while butterflies are often more colorful.
- Moths generally have larger bodies in proportion to their wings with longer scales covering them.
- Moths generally have straight, feathery or branched filaments, while butterflies often have clubbed antennae with small knobs on the end.
- When resting, butterflies often have their wings folded upright, like hands pressed together, while moths often rest with their wings open.

Procedure

1. In discussion or on paper, have students share everything they know about how moths and butterflies are alike and different. Use a variety of print materials to have students look at butterfly and moth species. Try to show some examples of them in their respective habitats.

Grade: 7-12

Key Concepts:

- Butterflies and moths share some similarities that place them together in the insect order *Lepidoptera*.
- Butterflies and moths have some differences.
- Butterflies and moths have evolved differently as they have adapted to different aspects of their environments over time.

Skills:

- Compare and contrast
- Read or listen for understanding

Materials:

- A variety of images of butterflies and moths (books, web, magazines)
- Characteristics of Butterflies and Moths sheet
- Glue
- Scissors
- Field guide to butterflies and moths

2. Distribute the Characteristics of Butterflies and Moths sheet to each student. Instruct students to cut out the various characteristics. They should then draw a Venn diagram (two concentric circles) large enough to accommodate these slips of paper.

3. Students sort the characteristics according to whether they belong exclusively to either moths or butterflies, or whether they are shared by both.

Students might work with a partner or check their work with a partner. Before gluing the characteristics into a Venn diagram, choose one or more of the following to give students information on similarities and differences:

- Allow them to use online resources to read about moths and butterflies
- Allow them to explore books

4. Go over the actual comparison/contrasts and then have students glue down their slips. Remind students that there are often exceptions to all generalizations, and that is true for moths and butterflies as well. One example the brightly colored Tiger Moth that is active during the day.

Characteristics of Moths and Butterflies

Cut out the following characteristics and begin to sort them by “butterflies only,” “moths only” or “both.”

6 legs (as adults)

compound eyes (as adults) head, thorax, abdomen

2 pairs of wings

hatches from an egg

makes a chrysalis

**usually (but not always)
has a proboscis**

is an insect

often spins a cocoon

has a spinneret (spins silk)

thick, feathery antennae

**wings upright when
resting**

**wings usually open when
resting**

**usually dull colored wings,
body**

**often brightly colored
wings**

often active at night

active during the day

**many long scales on a
thick body**

fewer scales on body

complete metamorphosis

2 antennae

Vocabulary

Abdomen – (AB-duh-men): the elongate hind part of the body, behind the thorax.

Adaptation – (A-dap-TA-shun): character that enhances the chances an organism will survive and reproduce.

Antenna – (an-TEN-uh), plural, **antennae** (an-TE-nee): sense organ on an insect’s head. In monarch larvae, these are often confused with the tentacles or filaments. Larval antennae are very small, while adult ones are much longer.

Aposematic coloration – (AP-uh-suh-MAT-ik): coloration that warns predators of distasteful prey.

Asclepias syriaca – (u-SKLEE-pee-us sir-i-uh-kuh): common milkweed, the most common host plant for monarch larvae in the upper midwestern US. Monarchs also eat other members of the genus *Asclepias*.

Camouflage – a French word that means to hide or disguise. There are two types of camouflage: protective resemblance and protective coloration. Protective resemblance is when something looks like something else in its environment. Protective coloration is when something has the same color or pattern as its surroundings.

Chemoreceptors – (KEE-moh-ree-SEHP-tors): cells that sense the presence of chemicals and relay that information to the organism. Taste and smell are sensed through chemoreceptors.

Chrysalis – (KRIS-uh-lis), plural, **chrysalides** (KRIS-uh-lids): another name for a butterfly pupa.

Cocoon – (kuh-KOON): a silk web that encloses the pupae of many moths, but not butterflies.

Danaus plexippus – (duh-NAY-us PLEX-uh-pus): the scientific name for a monarch butterfly.

Dichotomous key – a tool for identifying a species by narrowing down options that limit description to certain features.

Entomologist – a scientist who studies insects. The study of insects is called Entomology.

Exoskeleton – a hard skeleton located on the outside of an invertebrate’s body (in contrast to the internal skeleton of vertebrates) that protects it and serves as a point for muscle attachment.

Frass – the waste product of larvae, called “caterpillar poop” by most students. Monarch larvae produce a lot of this, especially in their later instars.

Instar – a period between larval molts. There are five of these periods in the growth of a monarch larva.

Larva – (LAR-vuh), plural, **larvae** (LAR-vee): the second stage, after the egg, in metamorphosis. Also known as caterpillar. Monarchs molt five times in their larval state, which lasts about 9-14 days.

Metamorphosis – (met-uh-MOR-fuh-sis): series of developmental stages through which insects become adults – a butterfly is transformed from an egg, to a larva/caterpillar, to a pupa, to a butterfly. There are two types of metamorphosis: incomplete (simple) and complete (complex). The four distinct stages of metamorphosis found in butterflies are considered complete metamorphosis. Incomplete metamorphosis does not have a prolonged immobile (pupa) stage.

Migration – movement of an organism or group from one habitat or location to another, usually periodic or seasonal movement of relatively long distance.

Mimicry – harmless animals that look like brightly colored, distasteful animals.

Molt – the process of shedding the skin or exoskeleton. Monarch larvae molt five times.

Palp – plural, **palpi**: paired appendages on an insect head used to sense – and test the quality of – food.

Phenology – (fe-NOL-o-gee): the science of seasonal changes and their affect on the natural world.

Pheromones – (FAIR-uh-mohns): special chemicals released by some animals to communicate with other members of their species. They may be sensed over long distances, and can help mates find each other. They may also help ensure that mating only occurs with other members of the same species.

Photoperiod – the amount of daylight hours.

Proboscis – (pro-BAHS-kiss): the adult monarch's feeding tube used for sucking nectar. The proboscis is coiled under the head when not in use.

Pupa – (PU-puh), plural, **pupae** (PU-pee): the third stage in metamorphosis, after the larval stage. In monarchs, this stage lasts 8-13 days.

Pupate – to change from a larva (caterpillar) to a pupa (chrysalis).

Scales – overlapping pieces of chitin (the same material of which exoskeletons are made) that insulate butterflies' bodies and wings, improve their aerodynamics and give them color and markings. Many people think the scales look like fine dust on butterfly wings.

Thorax – middle section of an insect's body. Wings, if present, and legs are attached to this segment.

Warning coloration – bright colors advertising poisons or other harmful defenses to potential predators. Also called aposematic coloration.

References

Web Sites

Flight of the Butterflies

www.flightofthebutterflies.com

Monarchs in the Classroom

<http://www.monarchlab.org/mitc/>

Monarch Watch

<http://www.monarchwatch.org/>

Fondo Mexicano para la Conservacion de la Naturaleza

<http://fmcn.org/?lang=en>

SK Films

www.skfilms.ca

Journey North

www.learner.org/jnorth/monarch

Maryland Science Center

www.marylandsciencecenter.org

Where to Find Live Specimens for Classroom Use

Monarch larva, milkweed and rearing kits available

www.educationalscience.com

Larvae

www.monarchlab.org at the University of Minnesota – ships to Minnesota and Wisconsin only

www.butterfliesetc.com

Larvae, eggs and milkweed

www.butterflyworkx.com

Larvae, adults

www.livemonarch.com

Life cycle kit

<http://monarchmagic.com/lifecycle.html>

Milkweed and larvae
<http://monarchwatch.org/>

Reading Materials for Younger Students

Monarch and Milkweed by Helen Frost, 2008 – pre-school-grade 2

Monarch! Come Play With Me by Ba Rea – 6-12 year olds

Monarch Magic!: Butterfly Activities & Nature Discoveries by Lynn Rosenblatt – 4-8 year olds

Great Butterfly Migrations by Laura Marsh, National Geographic Readers, 2010 – grades 2 and up

Monarch Butterfly by Gail Gibbons, 2011 – grades 2-4

Hurry and the Monarch by Antoine O’Flatharta 2005-grades K-4

Monarch Butterflies Life Cycles by Julie Murray 2007-preK-3

Reading Materials for Older Students and Adults

National Geographic Magazine, article by Fred Urquhart, August 1976

The Monarch Butterfly: International Traveler by Dr. Fred Urquhart

The Monarch Butterfly: Uniting a Continent by Karen Oberhauser, Monica Missrie, Eduardo Rendon and Eligio Garcia Serrano, 2003

Chasing Monarchs: Migrating with the Butterflies of Passage by Robert M. Pyle, 1999

Monarch Butterfly: A Wonder of Nature, edited by Juan C. Morales and Salvador F. Crotte, published by Industria Fotografique Mexiquense Editorial De C.V., 2008

The Amazing Monarch: The Secret Wintering Grounds of an Endangered Butterfly by Windle Turley, 2010

Learning from Monarchs – A Teachers Handbook by Ba Rea, 2010

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Flight of the Butterflies – The Giant Screen (IMAX) Film

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The project is fortunate to have world-renowned monarch butterfly research scientists and educators as main advisors:

- Dr. Lincoln Brower is Research Professor of Biology at Sweet Briar College. He began researching monarch butterflies in 1954 and was the first scientist to confirm that monarch butterflies are chemically protected against birds. He also used chemical tags in the butterflies to show that the fall migrants return from overwintering in Mexico to the Gulf Coast states the following spring.
- Dr. Chip Taylor is the Founder and Director of Monarch Watch and is a Professor in the Department of Ecology and Evolutionary Biology, University of Kansas. He started his career in August 1969, and in 1974, he established research sites and directed students studying Neotropical African honey bees (killer bees) in French Guiana, Venezuela, and Mexico. Monarch Watch is an organization that is a vital educational outreach program based at the University of Kansas, but has outreach to 100,000+ students and adults who participate in tagging activities each fall. It engages Citizen Scientists in large-scale research projects in relation to the monarch butterfly.
- Dr. Karen Oberhauser is an Associate Professor in the Department of Fisheries, Wildlife and Conservation Biology at the University of Minnesota. She began studying monarchs in 1984 and is the head of Monarchs in the Classroom, an organization dedicated to providing a solid background for understanding the biology of monarch butterflies and fostering an interest in their conservation.
- Dr. Steve Malcolm works on monarch migration and milkweed use at Western Michigan University.
- Dr. Barry Frost a neuroscientist, from the Psychology department of the University of Queen's in Kingston, Ontario, Canada, provided navigation and orientation expertise.

These individuals know there are still more discoveries to be made about the fascinating monarch butterfly and are working with a variety of exciting, new, scientific teams on remaining mysteries to enrich our understanding of the butterfly. In some cases, the butterfly research is shedding light on other insect, and even human, behavior.

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